Radio Controlled

Soaring Digest

April 2016 Vol. 33, No. 4

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April 2016

Vol. 33, No. 4

Front cover: Mike O'Riley launching his Blanik at Tapanappa Slope Fest 2016, South Australia. Photo by Adam Fisher
Nikon D200, ISO 320, 1/2000 sec., f6.3, 135mm

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Back cover: The benefits of living up north, flying just before 22:00 late in April. Seagull K8B flown at Stapinn near Keflavik, Iceland. Photo by Sverrir Gunnlaugsson
Canon EOS 500D, ISO 800, 1/160 sec., f25, 24mm

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In the Air

Corrections to Chuck Anderson's LilAn Omega Part 2, March 2016 issue: (1) Photo 21, page 12, utilized an incorrect image. The appropriate image is depicted here.

(2) Chuck's article on pipettes, referenced in the article, was in the November 2015 issue of *RCSD*. Corrected PDFs are now on-line.

FAI has ratified the following Class F (Model Aircraft) World record: Claim number 17625, F3 Open, Glider, Distance in a straight line: Pioche, Nevada (USA), 228.7 km / 142.1 mi., John A. Ellias (USA), 09.08.2015 (Due to rule changes, there was no previous record.)

Time to build another sailplane!

LilAn Omega Part 3

Chuck Anderson, chucka12@outlook.com

LilAn Omega Tail Surfaces

I think of sanding blocks with 80 grit sandpaper as my portable shaper. A sanding board is sandpaper glued to a flat board and is very useful in building tail surfaces (Photo 1).

I have built stabs, fins, and rudders with rectangular rib blanks and sanded to airfoils on a sanding board for the last 30 years. The rib blanks are slotted on the centerline for the leading and trailing edges. Templates glued to the end ribs allow the rib blanks to be sanded to a symmetric airfoil on a sanding board. This is the way I built the stab, fin, and rudder for my LilAn series of models.

Installing the stab horn and stab wires before sanding the airfoils to shape helps to give more accurate alignment and reduces the chance of built-in warps.

LilAn Stab

Structurally, the LilAn stab evolved from the 1976 Sailaire stab. I liked the light weight balsa I-beam spar with sufficient thickness to handle flight loads, but replaced the cap-strip ribs with real ribs. Before laser cutting, building with rectangular rib blanks


02


03

and sanding to an airfoil produced a light stab with simplified construction and is still the quickest and easiest way to build an experimental or one-off stab.

Aerodynamic design was based on “Stabilator Design” in the July 1977 issue of *Sailplane*.

Essential points from the article were (1) place the pivot at or slightly ahead of 25% the MAC, (2) balance the stab and horn about the pivot, (3) minimize weight aft of the pivot, and (4) rigidly connect left and right stabs.

The LilAn stab pivot is at 25% of the mean aerodynamic chord (MAC).

Reversing the bell crank places the heavy components ahead of the stab pivot to reduce the chances of flutter while the slight sweep of the stab allows the stab wires to be placed at the thickest part of the stab.

I have found that a thickness of 8 percent gives enough strength and control effectiveness with minimum structural weight. I have been unable to detect any dead band in flight while using a NACA 0008 stab airfoil with standard built up structures.

Adding weight to the leading edge is not normally required, but I once managed to control a launch flutter problem on my cross country sailplane by adding weight to the forward tip of the stabs. That sailplane had a 168 inch span and weighed 10 pounds. I could not throw it hard enough for a normal launch, so had to launch it level with a lot of towline tension. The stab would flutter violently during rotation to the climb. Adding 0.1 oz to the forward point of each stab brought the launch flutter under control.

LilAn uses stabs designed for my 1997 RES sailplane, Sirius II (Photo 2). This photo was taken in June 2001, two weeks after winning an RES contest in St. Louis Missouri and two weeks before it was lost in an eight plane mass launch in Cincinnati Ohio.

The prototype LilAn II used the stab and fin from a crashed model and retained the stab sweep from the swept tail


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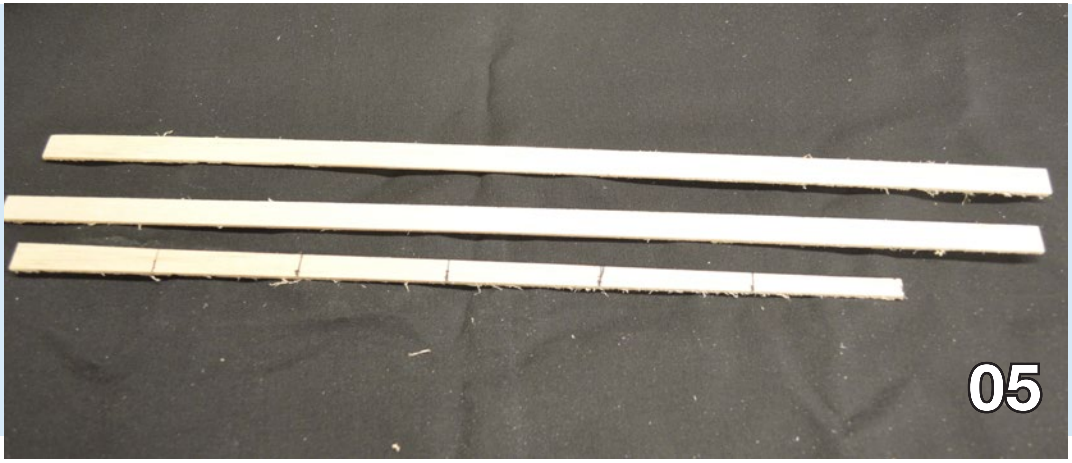
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surfaces made necessary by using a too short 1976 fiberglass fuselage for Sirius.

I finally build a new fuselage mold in 2005 that let me get away from the swept rudder hinge line, but I kept the swept stab to help identify my model. Photo 3 is the stab from the Sirius II that I flew in the 2003 Nats and now hangs above my office desk. It is identical to the stab used on Omega.

I use the largest stab horn that I can find to minimize the effects of wear and slop in the linkage. The best commercial stab horn I have ever found was the blue anodized aluminum horn sold by Tekoa about 20 years ago (right in Photo 4).

Unfortunately, the Tekoa stab horn is no longer available so I have to fabricate my own stab horns. The horn used in Omega was cut from a scrap of glass laminate from printed circuit boards (left Photo 4). The stab wire holes were bushed with brass tubes to minimize wear from installing and removing the stabs. Spacing of the stab wires was kept the same as the Tekoa horn so that stabs would be interchangeable.

My stabs are designed around the Tekoa stab horn and has approximately 15 degrees of spar sweep to place the pivot at 25 % MAC. Using a stab horn with the actuating wire closer to the pivot rod would allow use of less sweep but I like the sweep because it helps me identify my model in a thermal with other models.

The Sirius stab was designed with Model Design, a program I sold from 1990 until 2002. Model Design was a DOS program for designing wings, calculating MAC, and printing wing plans on dot matrix printers. In 1999, Model Design was ported to Windows 98 using Visual Basic 5 and added printing on inkjet and laser jet printers.

The stab with 12 degree sweep has a pivot 3.125 inches aft of the root leading edge; if the spar sweep is reduced to 7 degrees to eliminate the trailing edge sweep for building on a grid, the pivot will be 2.625 inches aft of the root leading edge.

This stab planform has been used for all my designs since 1974 with various sweep angles. Some of the stab photos show a stab plan printed on two 8.5 by 14 sheets on a laser jet printer with Model Design and were used to measure nose and tail rib lengths.

The stab has a NACA 0008 airfoil and an I-beam spar built with firm 1/16" sheet balsa. Photo 5 shows the parts for a stab spar while Figure 6 show a finished spar. The spar web is 12 inches long and

tapers from 3/8" high at the root to ¼" high at the tip. The spar caps are 15 inch long, 3/8" wide, and trimmed to length after assembly.

The stab is constructed with rectangular rib blanks that are carved and sanded to the airfoil after assembly. Only the root and tip ribs are complete ribs. The remaining ribs are made up of separate nose and tail ribs notched to fit the spar.

The rib blanks are cut from 1/16" balsa strips the width of the root rib. The trailing edge is 1/16" x ½" firm balsa while the leading edge is either 1/8" square hard balsa or 1/8" diameter birch dowel.

Rib blanks are cut from ½ inch wide strips ripped from 1/16" balsa. Root rib chord is 7 inches and tip rib chord is 5 inches while intermediate ribs are cut to length as required. This is where a plan is really useful, so Charlie has prepared a DXFstab drawing that can be downloaded from <http:rcsoaringdigest.com/Supplements/Anderson_LilAn/LilAn_DXF.zip>.

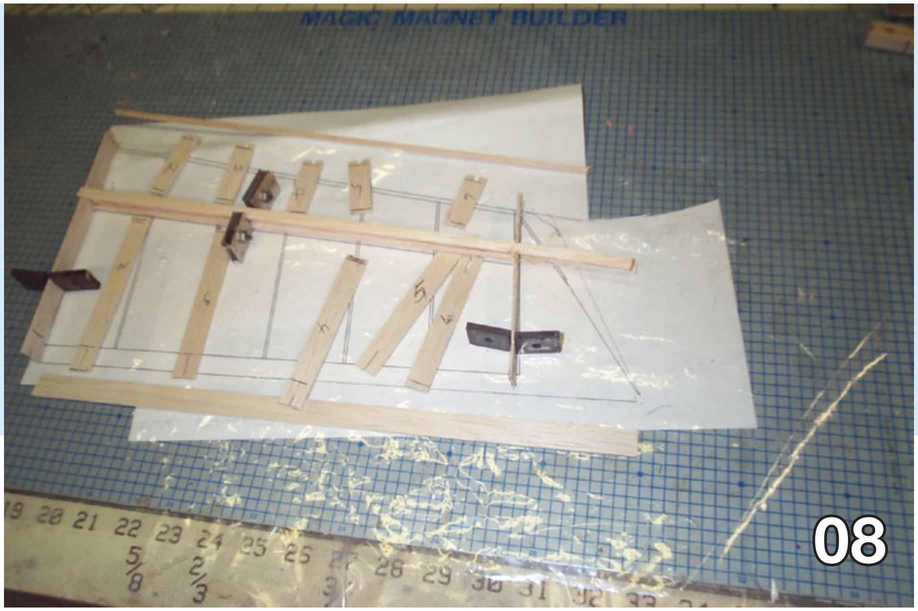
The rib blanks must be slotted on the centerline for the leading and trailing edges.

Photo 7 illustrates an easy way to accurately slot the rib blanks on the centerline using a band saw with a rip fence. Set the rip fence so that the cut is just slightly over half the height of the rib blank away from the fence.

Cut a slot the width of the trailing edge, flip the rib blank over, and run through the saw again. Make trial cuts with a scrap rib blank and adjust the rip fence until the slot is a snug fit on the trailing edge. Cut the slot for the end and tail rib blanks. Reset the rip fence and repeat the process for the leading edge slots.

Print root and tip rib templates and glue them to the root and tip rib blanks. The blanks are notched to fit under the spar caps.

Photos 8 shows all components of a stab ready for assembly. The nose and tail ribs have been slotted for leading and trailing edges but not yet notched for the spar caps.



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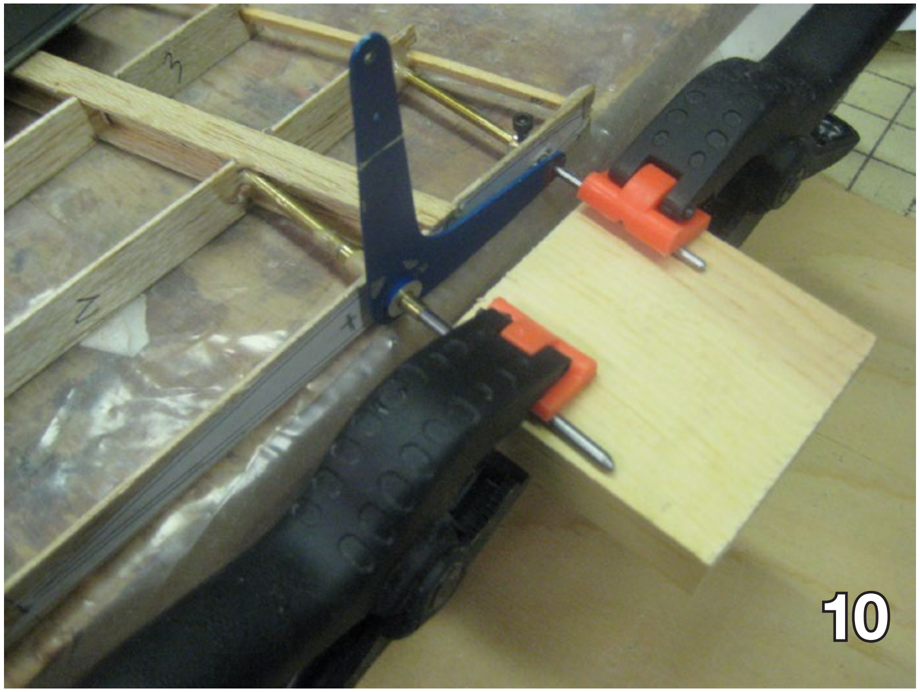
The leading and trailing edge rib blanks are then glued in place. I have found that thick CA works best for attaching the rib blanks to the spar. After all rib blanks have been installed, slide the leading and trailing edge in place and glue with CA (Photo 9). Install a 3/8 inch wide 1/16 balsa tip between the leading edge at the tip rib and the trailing edge 2 inches from the tip rib. Glue the spar caps to the tip and trim flush with the tip.

Build another stab. Assemble the stab horn, joiner wires, and wire tubes in a stab on a flat surface (Photo 10). The stab wires are clamped to a scrap of wood with parallel lines at the wing wire locations while epoxying the stab wire tubes in place to assure that the stab wires are parallel for easy installation and removal. The forward wire tube has a wheel collar with a set screw to clamp the stabs together after installation on the fin.

Assemble the stabs on a flat surface with the joiners and stab horn. (Photo 11) The rectangular rib blanks assure that both stab halves are at the same incidence angle.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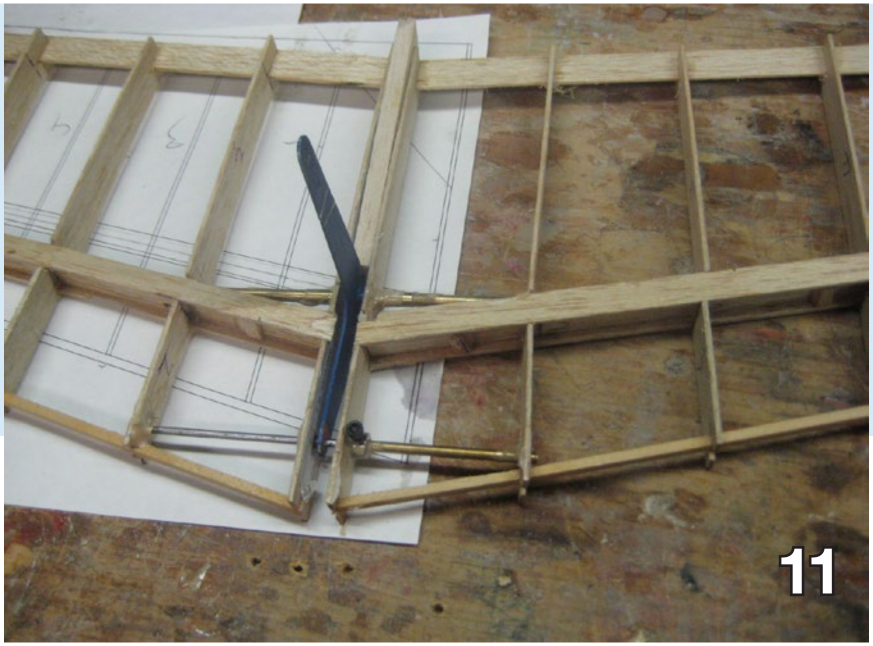
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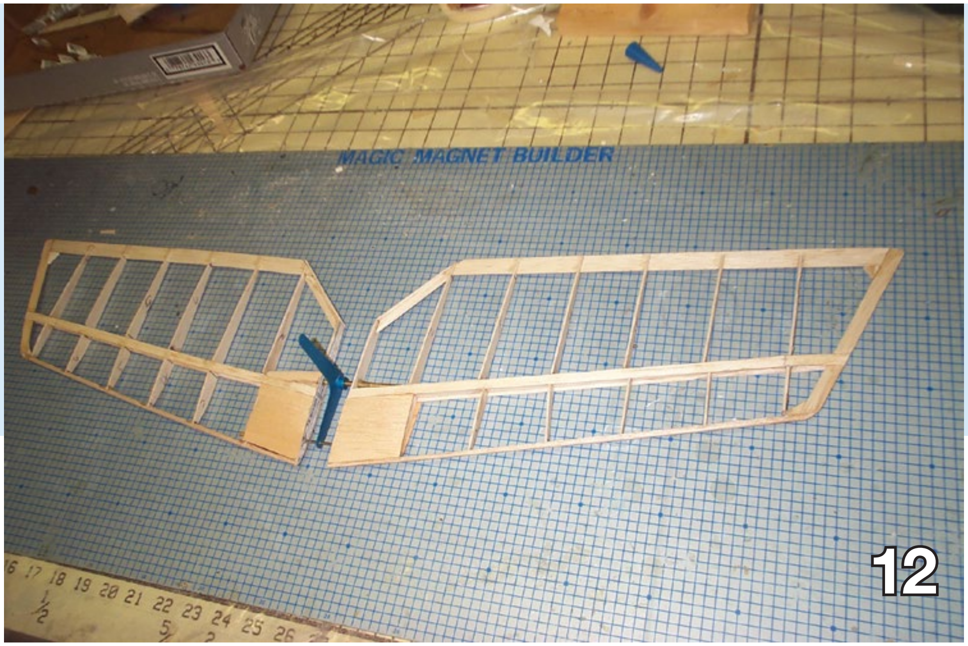

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When satisfied with the alignment, epoxy the other stab pivot wire tube and the forward stab wire in place.

The brass tube for the forward wire has a brass wheel collar with a set screw to clamp the stabs together. The extra weight of the wheel collar and clamping the stabs together help to minimize the chances of flutter.

Trim the rib blanks slightly oversize and finish sanding to the airfoil templates glued to the end ribs by pulling the ribs across the sanding board.

Sheet the section over the stab wires and cut away the trailing edge as necessary to clear the rudder (Photo 12).

The stab is now ready for final sanding and covering.

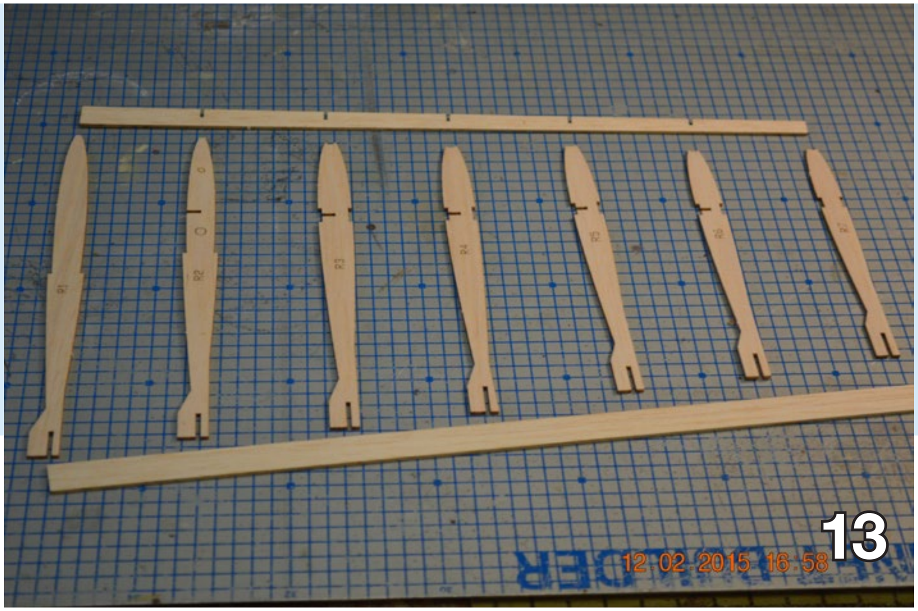
The stab depends on the covering for torsion stiffness. I have found that Super Monokote to be the best covering material for this application. I have tried other lighter covering material but always wound up stripping the covering and recovering with Super Monokote.

This is the way all LilAn stabs have been built so far. Charlie Bair has used his CAD skills to write a DXF file to laser cut the spar webs and ribs with tabs to assemble the stab on a flat board (Photo 13).

The precision of laser cutting makes it feasible to slot the ribs and spar web to interlock before gluing to the spar webs. Tabs on the rear of the ribs let the stab be accurately glued together on a flat surface.

The laser is accurate, but the balsa thickness is sometimes too thick to allow the ribs to be inserted in the spar web. If the balsa is too thick to let the rib slide into the web, it will be necessary to open up the slots with a small file (Photo 14).

The laser cut parts do not include the 15 inch long spar caps so they will have to be hand cut. The ribs are cut for a spar cap that tapers from 3/8" at the root to ¼" at the tip rib.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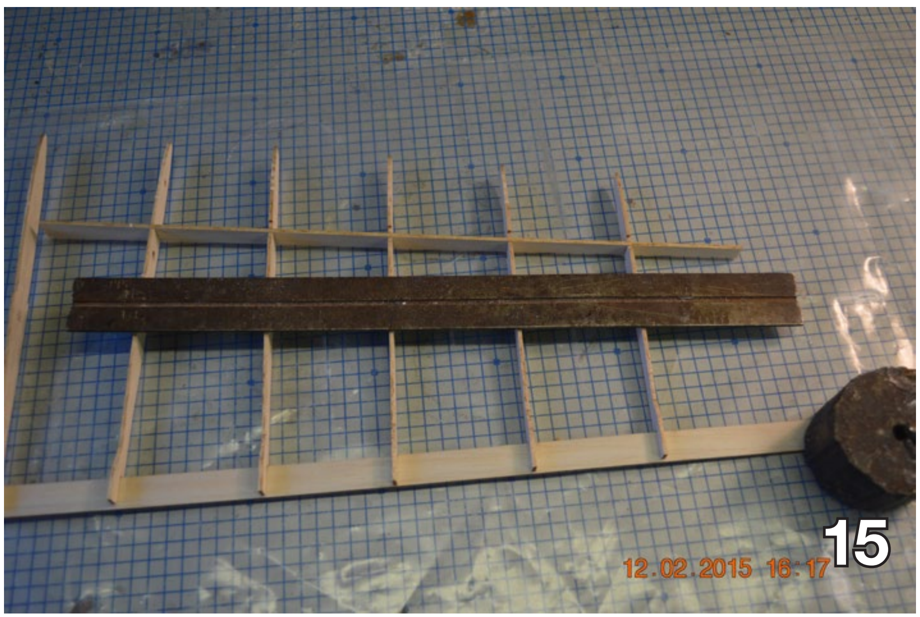
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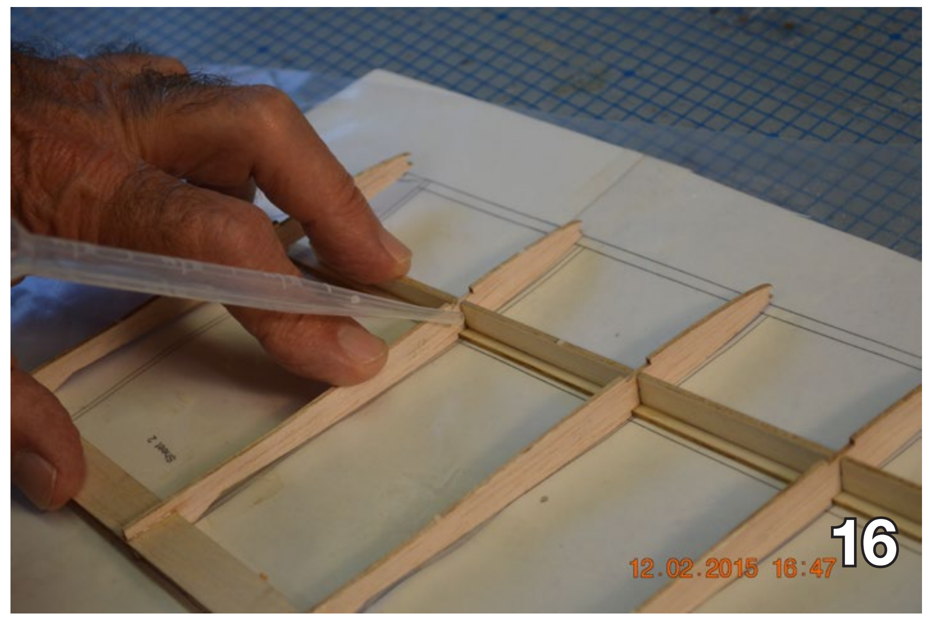
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The egg-crated rib and spar can be aligned with the desired sweep before gluing with CA.

LilAns to date have used 12 degrees spar sweep which results in a trailing edge sweep of 5 degrees. For building on a grid, remove the trailing edge sweep by aligning the trailing edge and ribs on a grid is a more practical solution (Photo 15).

Charlie has produced a CAD drawing of the 15 degree swept stab and has uploaded a DXF file. Assemble the stab over the bottom spar cap and glue all joints with CA (Photo 16).

Install the top spar cap and leading edge. Build another stab being sure to build left and right stabs. Then install the stab horn and finish on a sanding board as done with stabs built with rectangular rib blanks (Refer to Photos 10, 11, & 12).

I have never had a stab flutter problem with either the Sirius or LilAn stabs, but Charlie Bair encountered stab flutter strong enough to rip light covering in an aggressive zoom.

I cover my stabs with Monokote and don't see my models well enough to get any advantage from an aggressive launch, especially when launching off a 300 meter winch.

Charlie modified the laser cut ribs to use a D-tube leading edge. The D-tube stab uses 1/16" balsa skin instead of spar caps. The leading edge of the D-tube ribs are slotted for 1/16" x ¼" leading edge to hold the ribs in position while sheeting the leading edge as is done for the fin build.

DXF cut files for standard and D-tube stabs can be downloaded from <http:rcsoaringdigest.com/Supplements/Anderson_LilAn/LilAn_DXF.zip>

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Fin

The fin of LilAn II prototype was modified from a crashed Sirius II by extending the root of the fin to remove the swept rudder hinge line in order to simplify the rudder linkage and eliminate the need for a ball link connection to the rudder horn.

The fin is framed with ½" wide 1/16" balsa rib blanks and spar. The leading edge of the rib blanks is slotted on the centerline for ¼" wide 1/16" balsa leading edge (Photo 17). The leading edge is to hold the ribs until the first side is sanded to the airfoil shape and glued to the skin. The top of the fin spar is also slotted for the ½" wide 1/16" balsa tip.

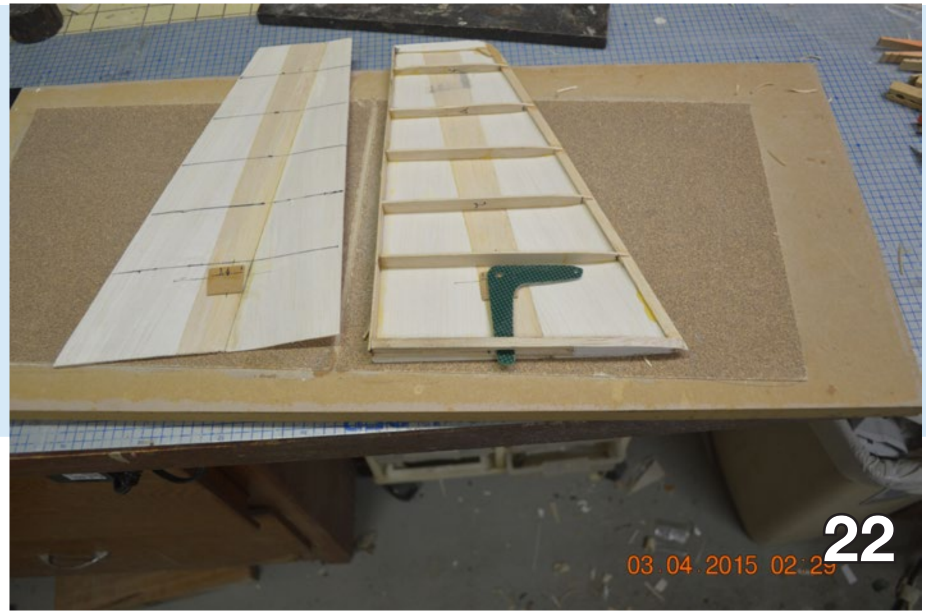
The fin is 11 inches tall with a 7 inch root chord and a 3 inch tip chord with a vertical hinge line.

Splice enough 1/16" sheet balsa to cut two fin skins. Use the stab horn to locate the stab pivot rod on the fin and glue a 1/16" plywood doubler for the stab bearing. Drill a 1/8" pilot hole in the doublers before gluing to the inside of the fin skins.

The root rib blank is 1/4" thick soft balsa and slotted for the stab horn. A template for a symmetric leading edge is glued to the root rib ahead of the stab horn. Draw lines at the rib locations on the inside of a fin skin.

Rib location is not critical as long as the ribs are clear of the stab horn. The fin tapers in thickness fom 0.625 inches thick at the base to 0.375 at the tip rib so the spar will have to taper from ½ to 1/16 inch during assembly. Draw the taper on the spar from the height of the stab pivot rod to 3/16 inch at the tip. Photo 17 shows all fin components ready to start assembly.

Trim the upper edge of the spar for the taper before starting assembly. Cover the skin with the rib locations with plastic and use it as a plan to assemble the fin frame (Photo 18).



Trim the rib blanks to slightly higher than the spar and carefully sand in the fin taper on the sanding board (Photo 19). The frame is very fragile at this point so carefully sand the ribs by pulling them across the sanding board.

Then sand the leading edge airfoil and taper the top of the spar on the sanding board (Photo 20).

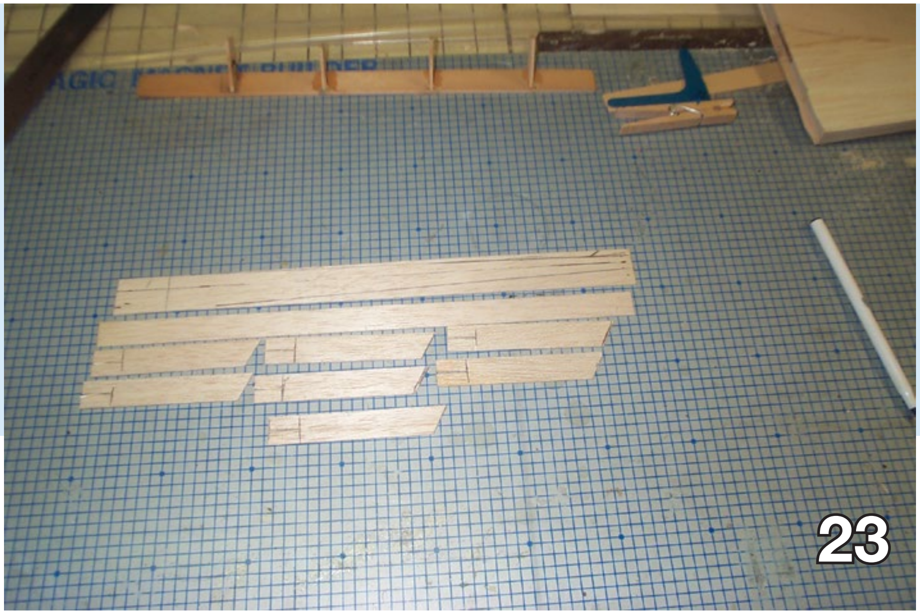
Place the shaped side of the fin on the skin and glue with CA. Move the fin to the edge of the building board and clamp the skin to the leading edge and tip with clothes pin to glue the ribs and leading edge to the skin (Photo 21).

Sand the taper and leading edge of the other side. Check that the stab horn can be removed and installed through the slot in the root rib before gluing the other skin to the ribs (Photo 22).

It took less than an hour to go from Photo 17 to leaving the fin pinned to the other skin and left under a weight over night for the Titebond to dry.

Rudder

The rudder is also built entirely of 1/16" balsa. The rudder is 4 inches wide and 11.5 inches tall and hinged on one side with hinge tape. The leading edge is beveled for a maximum fin deflection of 30 degrees. I never use more than 20 degrees of rudder deflection. Anything more is just drag so if 20 degrees isn’t enough, I increase the rudder size and/or the wing dihedral.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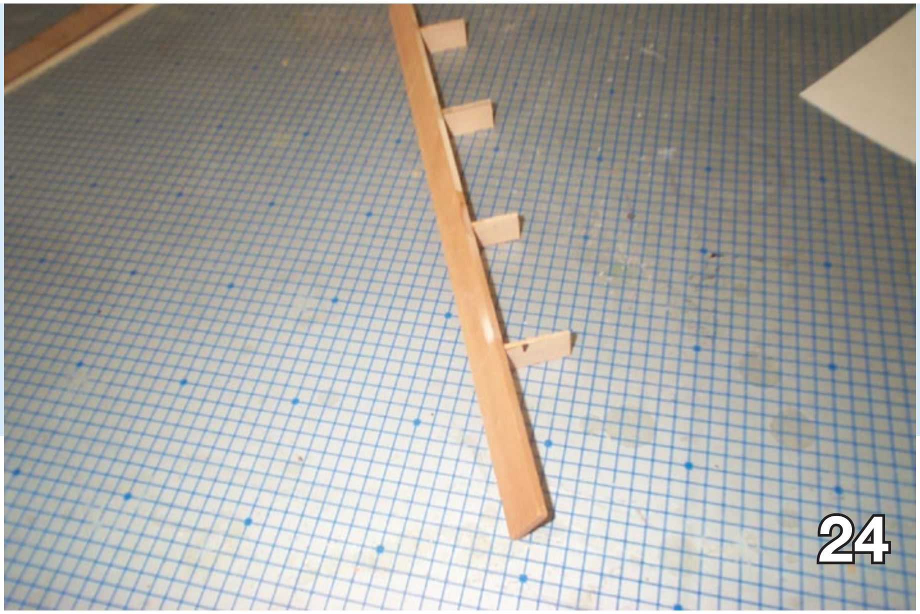
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MAGIC MAGNET BUILDER
26

27

28

The rib blanks are beveled 60 degrees on the Miter Cut and slotted on the band saw for the trailing edge. Rib blanks are ½" wide and 4 inches long. The trailing edge is ½" wide and 12 inches long while the leading edge is ¾" wide and 12 inches long. Photo 23 shows all rudder parts ready for assembly.

Assembly of the rudder is much easier if a simple jig is constructed to hold the leading edge 60 degrees (Photo 24).

The jig was constructed from scrap wood in a couple of minutes. The rudder leading edge is clamped to the jig with clothes pin while gluing the ribs to the leading and trailing edges. The bottom rib is a double rib with a slot for the rudder horn (Photo 25). Root and tip fairings are installed after the fin is glued to the boom so the rudder horn can be lined up with the rudder pushrod.

Hold the assembled rudder against the fin and trace the fin on the rudder leading edge. Trim the leading edge and ribs oversize before sanding the rudder to near final shape.

Place the fin and rudder on the sanding board and sand to match the thickness (Photo 26). The sanding board holds them in position while matching the rudder to the fin. Be sure that the hinge line is straight (Photo 27).

Contour the base of the fin to match the boom (Photo 28).

Part IV of this series will cover installing the radio gear in the fuselage, constructing the wing mount, spoiler strings, and fin installation. This series will conclude with setting up your LilAn for its first flight.

Introduction to TP-2016-219072

Prandtl, Horten, Jones, Klein and Viswanathan, and Bowers are names with which long-time readers of RC Soaring Digest may be familiar, particularly if interested in the aerodynamics and structures of wings.

Prandtl (1920) proposed the elliptical lift distribution as being the most efficient if span is limited. About a dozen years later (1933) he formulated a more efficient wing for those circumstances where span is not limited. The Hortens used Prandtl's guidelines not to specifically increase efficiency, but rather to counter adverse yaw. Unaware of Prandtl's latter work, R.T. Jones presented a similar idea with nearly identical increases in efficiency while retaining the same bending moment at the wing root as that of the elliptical wing. Klein and Viswanathan then successfully expanded the conditions to include no increase in the shear moment at the wing root.

An overview of these ideas has been presented in our own "On the 'Wing..." articles numbered 161 to 164. These articles are now available as a single document at:
<http://www.rcsoaringdigest.com/Supplements/OTW_161-164.pdf>.

Al Bowers, intrigued by the unique performance of one of the later Reimar Horten designs, went about determining an appropriate bell shaped lift distribution twist paradigm for a tailless swept wing. Two swept wing radio controlled flying models have now shown the BSLD to make possible both efficient flight and coordinated turns without a vertical surface.

Several of Al's slide programs dealing with the BSLD concept have been available through the NTIS for some time, but the big news is that he has just made available a NASA Technical Paper on the subject of the bell shaped lift distribution, NASA/TP-2016-219072. Our sincere thanks to Al Bowers for granting permission to reprint this document in *RCSD* and placing the PDF on the *RCSD* web site!

<http://www.rcsoaringdigest.com/Supplements/219072.pdf>

NASA/TP—2016–219072

On Wings of the Minimum Induced Drag: Spanload Implications for Aircraft and Birds

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Armstrong Flight Research Center, Edwards, California

Robert "Red" Jensen, and Brian Eslinger
Jacobs Technology, Inc., Edwards, California

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March 2016

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Abstract

For nearly a century Ludwig Prandtl's lifting-line theory remains a standard tool for understanding and analyzing aircraft wings. The tool, said Prandtl, initially points to the elliptical spanload as the most efficient wing choice, and it, too, has become the standard in aviation.

Having no other model, avian researchers have used the elliptical spanload virtually since its introduction. Yet over the last half-century, research in bird flight has generated increasing data incongruous with the elliptical spanload.

In 1933 Prandtl published a little-known paper presenting a superior spanload: any other solution produces greater drag. We argue that this second spanload is the correct model for bird flight data. Based on research we present a unifying theory for superior efficiency and coordinated control in a single solution. Specifically, Prandtl's second spanload offers the only solution to three aspects of bird flight: how birds are able to turn and maneuver without a vertical tail; why birds fly in formation with their wingtips overlapped; and why narrow wingtips do not result in wingtip stall.

We performed research using two experimental aircraft designed in accordance with the fundamentals of Prandtl's second paper, but applying recent developments, to validate the various potentials of the new spanload, to wit: as an alternative for avian researchers, to demonstrate the concept of proverse yaw, and to offer a new method of aircraft control and efficiency.

Introduction

In 1922 Ludwig Prandtl published his "lifting line" theory in English; the tool enabled the calculation of lift and drag for a given wing. Using this tool results in the optimum spanload for minimum induced drag (the greatest efficiency) for a given span, which, Prandtl said, was elliptical (ref. 1). Since then, the lifting line theory and elliptical spanload have become the standard design tool and wing spanloading in aviation. So ubiquitous is it that avian researchers have relied on it to explain bird flight data almost since its introduction. But in 1933 Prandtl published a second paper on the subject in which he conceded that his first conclusion was incomplete: there was a superior spanload solution to maximum efficiency for a given structural weight. "That the wingspan has to be specified," he wrote, "leads to the invalid assertion that the elliptical distribution is best" (ref. 2). His new bell-shaped spanload creates a wing that is 11 percent more efficient and has 22 percent greater span than its elliptically-loaded cousin, all while using exactly the same amount of structure. It results in the minimum drag solution in every case of physical wings: any other solution will produce greater drag. Oddly, Prandtl's second spanload remains virtually unknown.

Sometime around 1935 Reimar Horten independently derived an approximate equivalent to Prandtl's 1933 solution. Horten dubbed it "bell shaped" for its wing loading. The extant evidence shows sufficient differences between the two men's methods, objectives, and conclusions to exclude any mingling of information on this subject despite being contemporaries. While Prandtl calculated the total induced drag for a wing with this new spanload, he did not examine the distribution of the induced drag across the span, and so he missed its implications. Horten, on the other hand, did calculate the induced drag across the span of the wing, and in 1950 concluded that something singularly possible existed with such a spanload, although he never conclusively proved it (refs. 3, 4). What Prandtl missed and Horten believed existed with respect to the alternate spanloading (the bell) is proverse yaw. Figure 1 shows the elliptical and bell spanloads of Ludwig Prandtl.

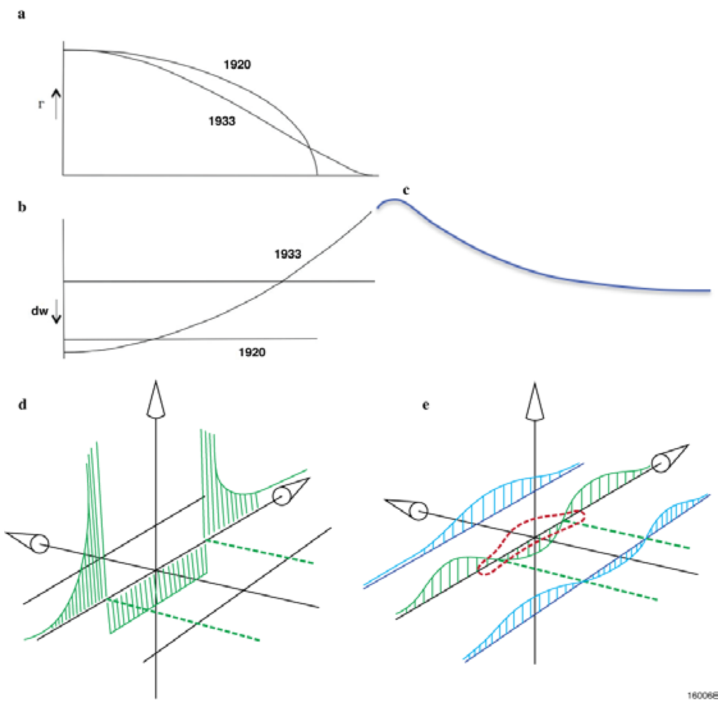

Figure 1. The elliptical and bell spanloads of Ludwig Prandtl.

Figure 1(a) shows Prandtl's elliptical spanload from 1920 and the bell spanload from 1933. The symbol gamma (Γ) signifies the airflow circulation about the wing. Figure 1(b) shows the matching downwash (dw) of the elliptical spanload (1920) and the downwash of the bell spanload (1933). In figure 1(c) the upwash outboard of the wingtip is shown. Figure 1(d) shows the 1920 Prandtl elliptical spanload downwash and upwash (note the sharp discontinuity at the wingtip, which is the wingtip vortex). Figure 1(e) shows the 1933 Prandtl spanload downwash and upwash (in contrast to the 1920 solution, note the smooth, continuous upwash across the wing and beyond; the wing vortex is now inboard of the tips). A comparison of the flow fields resulting from the elliptical and bell spanloads is shown in figures 1(d) and 1(e). The elliptical spanload wing, figure 1(d), has a sharp discontinuous slope at the wingtip span location in the upwash (this is the location of the wingtip vortex), in contrast to the smooth curve of the new upwash, figure 1(e) with no discontinuity (a weak vortex forms at the point where the downwash crosses the zero line and becomes upwash).

2

Prandtl's 1933 solution is stated as

$$L = (1 - x^2)^{3/2}$$

where L is the nondimensional local load (this is also expressed as gamma or Γ); and x is the span location between 0 and 1. Subsequently,

$$DW = 3/2 (x^2 - ½)$$

where DW is the nondimensional downwash (angle) of the flow.

The lift approaches zero at the wingtip, as shown in equation (1):

$$\lim_{x: 0 \to b/2} L(x) = 0 \qquad (1)$$

The slope of the lift (as a function of span) approaches zero at the wingtip, as shown in equation (2):

$$\lim_{x: 0 \to b/2} \frac{dL(x)}{dx} = 0 \qquad (2)$$

The slope of the upwash (as a function of span) at the wingtip is equal on both sides of the wingtip, as shown in equation (3):

$$\lim_{x:0 \to b/2} \frac{d\,DW(x)}{dx} = \lim_{x:\infty \to b/2} \frac{d\,DW(x)}{dx} \qquad (3)$$

Induced Drag, and Adverse and Proverse Yaw

It is critical to understand the airflow and forces exerted on a wing during flight, including lift and induced drag, to appreciate the differences between the elliptical and bell spanloads, and the implications for birds and aircraft.

Ludwig Prandtl described both the elliptical (1920) and bell (1933) spanload distributions as shown in figure 2. The 1920 elliptical spanload, figure 2(a), describes a wing with a uniform downwash along the wing's trailing edge, and a sharp discontinuity of downwash and upwash at the wingtip, which results in a strong, tightly-rolled vortex formed at the wingtip. In contrast, the bell spanload describes a wing having a downwash that varies from strong downwash near the wing root, which tapers outboard (past b/2 = 0.704), to upwash near the wingtip. The bell spanload is also much more heavily loaded (more net force) in the root area of which the large root downwash is a consequence. The significance of these disparate characteristics is both subtle and dramatic.

3

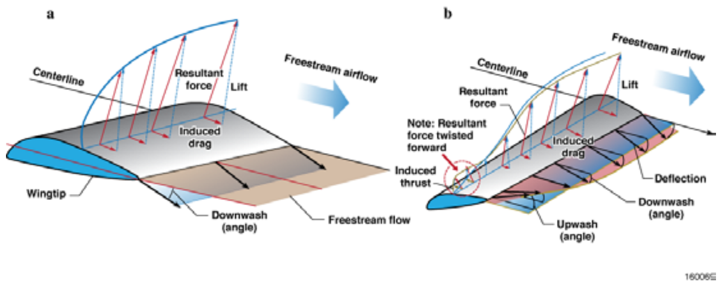

Figure 2. Prandtl's elliptical and bell spanloads explained.

Figure 2(a) shows Prandtl's elliptical spanload from 1920; figure 2(b) the bell spanload from 1933. The symbol gamma (Γ) signifies the airflow circulation about the wing. The matching downwash (dw) of the elliptical spanload and of the bell spanload for each are also shown. The upwash on the 1920 Prandtl elliptical spanload is outboard of the wingtip. Of importance in the elliptical spanload shown in figure 2(a) is that the net force vector field is tilted backwards by the constant downwash along the entire span of the wing. The resulting horizontal component of the resultant force (Γ) manifests itself as induced drag across the entire wingspan. By contrast, in figure 2(b) it can be seen that the 1933 Prandtl bell spanload and downwash show the twisted downwash crossing the zero line and becoming upwash near the wingtip. The resultant force is tilted forward of the vertical and the horizontal component is manifested as induced thrust at the wingtip, due to the resulting upwash.

Airflow over a wing generates a net force, which is approximately normal to the wing chord. As shown in figure 2(a) for an elliptic spanload, this resultant force vector is not exactly perpendicular to the airflow. The larger component perpendicular to the relative wind is known as lift. For finite wings there exists a component parallel to the relative wind (for elliptical spanload, always in the direction with the wind, that is, toward the trailing edge) that is referred to as induced drag. Induced drag is the "cost" of producing lift with a finite wing. As lift increases, induced drag also increases. Thus, any control surface deflected to locally produce more lift will also locally produce more drag. Ailerons deflected anti-symmetrically to generate a rolling moment will also produce a yawing moment to the outside, or against the turn being generated by the roll. This phenomenon is referred to as adverse yaw and is the reason all aircraft with an elliptical spanload require an auxiliary yaw device (typically a rudder, courtesy of the Wright brothers in 1902 [refs. 5, 6]) to counter the adverse yaw in order to coordinate the turn (yaw with the turn).

For the bell spanload, shown in figure 2(b), the net force vector is such that it varies along the span. Inboard, the force vector is tilted away from the relative wind, like that of the elliptical spanload case, and the parallel component produces induced drag. Progressing outboard, this parallel component reduces in magnitude until it eventually (past $b/2 = 0.704$) is tilted into the relative wind. This phenomenon is referred to as induced thrust (that is, negative induced drag). It should be noted that the sum total force of this parallel component is still producing a net drag (and this sum total is more than that of an elliptical spanload for the same span - in our case we are able to increase the span and achieve less total induced drag), but locally for the outer 0.296 span, it produces thrust. A control surface placed in this local thrust region will generate increasing thrust with increasing lift. Thus an aileron located in this region will produce a yawing moment into the turn, which moment is referred to as a proverse yawing moment. A properly designed aileron, on a bell spanload wing, could produce just the right amount of proverse yaw such that an auxiliary yaw device would be entirely unnecessary for coordinated turning flight. A design without an auxiliary yaw device means there would be neither added drag nor complexity from such a device. It should be noted that this does not mean for all aircraft designs employing a bell spanload that an auxiliary yaw device would not needed. There are instances on modern aircraft designs (for example, engine-out or crosswind landing) in which such a device would still be needed, but there could be designs for which such a device would not be required. Various bird species appear to maneuver gracefully with very minimal auxiliary yaw devices, and some seemingly have no discernible auxiliary yaw device. Further, as Prandtl pointed out in 1933, it is possible to extend the wingspan of a bell spanload, achieve the same lift and the same integrated wing bending moment, and achieve less induced drag than the equivalent elliptical spanload. This final solution is examined here.

The downwash/upwash curve of the bell spanload is one smooth and continuous function from beyond one wingtip, across the wing to beyond the opposite wingtip. Note that the slope of the downwash/upwash function will also be continuous across the wing. The upwash curve rises from the equilibrium level of the air far beyond the wing tip to a gentle peak at the maximum upwash of the wing, located outboard of the wingtip, which we show as an extension of Prandtl's downwash/upwash. Inboard of the peak, the upwash decreases and meets the upwash of the wing at the wingtip, and the two upwash curves, inboard and outboard, must be of equal slope.

As with any other aircraft, to turn we deflect the control surfaces near the wingtips, increasing the lift near one wingtip, resulting in the desired bank angle. But when we increase the lift on one wingtip the resulting induced thrust also increases (there is always thrust at the wingtips). The raised wing will create more thrust than the lowered wing, resulting in both bank and yaw in the direction of the turn: proverse yaw. As a result of this proverse yaw, coordinated flight is achieved without the need for a tail, rudder, or other drag devices.

Figure 3(a) shows the downwash field behind a wing using the bell spanload through use of twist (Marko Stamenovic). Figure 3(b) shows the vortex roll-up behind the wing, analytical and in flight (Marko Stamenovic and Tom Tschida, NASA photo).

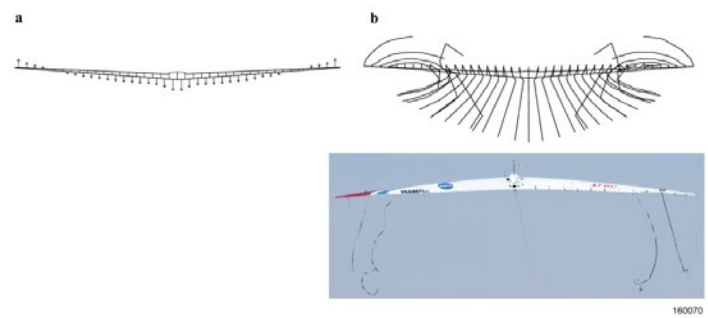

Figure 3. Downwash field, wing vortex roll-up, and resulting wingtip overlap in bird formations.

The Experiment

To validate the theory and the most critical principles of the bell spanload, we conducted an experiment using two subscale flying wing aircraft that used wing twist to achieve the selected bell shaped spanload. The model planform with a bell shaped spanload based on Prandtl's theory was a 25-percent Horten H Xc aircraft (12.3 ft span) with a design lift coefficient of 0.6. The objective of the experiment was to demonstrate coordinated flight with proverse yaw for an aircraft with a bell shaped spanload and no vertical surfaces of any kind on the aircraft. The elevons have equal and opposite throws while functioning as ailerons. There is no differential bias; this is a direct, stick to surface control system.

The Bell Spanload Aircraft Experiment

The radio-controlled aircraft were bungee-launched and flown by a pilot on the ground. Bungee tension was roughly 50 lb at release and typical altitude at separation from the bungee/cord was 200 ft above ground level. The pilot flew the aircraft on a single racetrack pattern during its descent and landing on the dry lakebed from whence it launched, completing various flight dynamics maneuvers en route to collect data. Flight times increased as experience grew, reaching a maximum flight time of 1 min 55 s and averaging nearly 1 min 22 s per flight on aircraft no. 2. Nearly 3 hr of flight time has accumulated.

The first aircraft carried an on-board data collection system: a smartphone with a triad linear accelerometer and triad angular rate recording application. This aircraft also later flew with a microcomputer-based flight data recorder providing basic inertial measurement unit functionality (pitch rate, roll rate, yaw rate, airspeed, and heading). The data sensors included global positioning system, pitot/static system, alpha/beta probes, and control position transducers. Configuration 3 had an open-source data recorder and autopilot, inertial measurement unit, global positioning system, pitot/static system, alpha/beta probes, and control position transducers. All data-gathering and -generating systems were calibrated before flight. Data were downloaded after each flight for later analysis.

Mass Properties

The aircrafts' mass properties are: roll inertia 5.425 slug-ft^2; pitch inertia 0.2717 slug-ft^2 (estimated); yaw inertia 5.818 slug-ft^2; and x-z plane cross product of inertia 0.5054 slug-ft^2. The inertias were measured using a bifilar method, except for pitch inertia, which was estimated from the computer-aided design geometry and the point mass locations of the onboard systems. The center of gravity was placed at 0.128 of the mean aerodynamic chord. The aircraft mass was 14.5 lb. The lateral-directional mass properties proved to be critical to the experiment. Maine and Iliff (ref. 7) show a very high sensitivity to x-z plane cross product of inertia in the estimation of Cnda (yawing moment due to aileron deflection coefficient).

Data Parameters

We gathered flight mechanics data for the aircraft with instrumentation for the following parameters: angle of attack (-20 to 70 deg); angle of sideslip (-45 to 45 deg); total pressure (0 to 2.16 lb/ft^2); static pressure (0 to 2.16 lb/ft^2); normal acceleration (+/-6 g); axial acceleration (+/- 4 g); lateral acceleration (+/- 4 g); roll rate (+/- 200 deg/sec); pitch rate (+/- 200 deg/sec); yaw rate (+/-100 deg/sec); left elevon deflection (+/- 90 deg); and right elevon deflection (+/- 90 deg). The sampling rate was 20 samples per second for all parameters. Open-source microprocessor systems were used for all data collection.

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Preliminary Design

We performed preliminary design analyses using two methods: a vortex-lattice model paneling the aircraft as 320 discrete surfaces (ref. 8), each of the discrete surfaces with its own angle; and a build-up of two-dimensional airfoil panel methods (7 span locations, with 5 control surface deflections, 5 chord Reynolds numbers varying from 200,000 to 2,000,000, and at 9 angles of attack from -2 deg to 10 deg). The build-up of the two-dimensional airfoils was integrated in MATLAB (The MathWorks, Inc., Natick, Massachusetts). The airfoils and twist are detailed in Tables 1, 2, and 3. A converged solution was declared between the two result sets when we achieved a four-significant-digit match. The airfoils were custom-designed using the Eppler code (refs. 9, 10). Estimates of the control surface effectiveness were made from the vortex-lattice results and adjusted on the basis of boundary layer thickness. The control surface effectiveness was also adjusted on the basis of the control surface configuration change (plain surface to plain surface with balance added) for the scale of the aircraft. The model scale was set at 25 percent, however, the mass of the vehicle increased due to the addition of the instrumentation package. The resulting wing loading placed the subscale aircraft in the range of the full-scale wing loading; consequently the subscale aircraft flew at velocities closely matching the full-scale aircraft predictions. The wingspan is 12.3 ft with a leading-edge sweep of 24 deg at the nose.

With this in mind for the analysis, the common use of Oswald's efficiency factor ("e") is also not appropriate for bell spanloads. Perhaps the invention of a Prandtl efficiency factor ("p") or a bell efficiency factor ("b") should be used for these Prandtl 1933 bell spanloads. A comparison of the elliptical and bell spanload efficiency parameters is given in table 4.

The coordinate frame for the flight mechanics data on the aircraft is: origin at the center of gravity (12.875 inches aft of the nose); x-axis is positive forward out the nose; y-axis is positive out the right wing; and z-axis is positive down out the bottom of the aircraft. Using a right-hand convention; roll is rotation about the x-axis and is positive for roll right; pitch is rotation about the y-axis and is positive for pitch up; and yaw is rotation about the z-axis and is positive yaw right.

The coordinate frame is: for the wing definition, the x-axis origin is at the wing centerline and extends to b/2 (half-span). The y-axis is defined as vertical upward (though in specific cases it is defined otherwise, and the convention should be apparent by the context).

The aircraft design was generated to produce a bell spanload. The airfoils vary continuously and linearly from the centerline to the tip. The airfoils are specified in nondimensional coordinates. The airfoils used are shown in tables 1 and 2.

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Table 1. Airfoil section, centerline.

Wing centerline airfoil							
x	y	x	y	x	y	x	y
0.99839	0.01595	0.33928	0.09971	0.00107	-0.00520	0.40245	-0.01754
0.98664	0.01580	0.30866	0.09846	0.00428	-0.00882	0.43474	-0.01602
0.95215	0.01710	0.27886	0.09632	0.00961	-0.01205	0.46730	-0.01451
0.89696	0.02355	0.25000	0.09339	0.01704	-0.01502	0.50000	-0.01301
0.82387	0.03690	0.22221	0.08978	0.02653	-0.01800	0.53270	-0.01156
0.80438	0.04073	0.19562	0.08553	0.03806	-0.02062	0.56526	-0.01017
0.77779	0.04590	0.17033	0.08072	0.05156	-0.02237	0.59755	-0.00885
0.75000	0.05124	0.14645	0.07539	0.06699	-0.02406	0.62941	-0.00761
0.72114	0.05668	0.12408	0.06963	0.08427	-0.02524	0.66072	-0.00646
0.69134	0.06218	0.10332	0.06345	0.10332	-0.02598	0.69134	-0.00542
0.66072	0.06768	0.08427	0.05691	0.12408	-0.02642	0.72114	-0.00448
0.62941	0.07312	0.06699	0.05017	0.14645	-0.02653	0.75000	-0.00364
0.59755	0.07840	0.05156	0.04318	0.17033	-0.02631	0.77779	-0.00291
0.56526	0.08341	0.03806	0.03575	0.19562	-0.02584	0.80438	-0.00227
0.53270	0.08800	0.02653	0.02897	0.22221	-0.02512	0.82005	-0.00194
0.50000	0.09201	0.01704	0.02201	0.25000	-0.02419	0.89553	0.00255
0.46730	0.09530	0.00961	0.01424	0.27886	-0.02308	0.95184	0.00908
0.43474	0.09777	0.00428	0.00784	0.30866	-0.02184	0.98662	0.01411
0.40245	0.09936	0.00107	0.00353	0.33928	-0.02047	0.99839	0.01595
0.37059	0.10000	0.00000	0.00000	0.37059	-0.01904		

Table 2. Airfoil section, wingtip.

Wingtip airfoil							
x	y	x	y	x	y	x	y
1.00000	0.00070	0.40620	0.04556	0.00002	-0.00038	0.46904	-0.04274
0.96091	0.00428	0.38108	0.04644	0.00028	-0.00161	0.48162	-0.04208
0.94833	0.00540	0.36853	0.04682	0.00174	-0.00435	0.49420	-0.04139
0.93571	0.00654	0.35599	0.04716	0.00460	-0.00763	0.50678	-0.04067
0.92307	0.00769	0.34346	0.04745	0.00681	-0.00956	0.54455	-0.03836
0.89778	0.00999	0.33093	0.04770	0.01384	-0.01430	0.55715	-0.03754
0.88515	0.01114	0.29342	0.04814	0.01925	-0.01718	0.56975	-0.03670
0.84728	0.01455	0.26848	0.04816	0.02619	-0.02030	0.59495	-0.03496
0.82206	0.01679	0.25604	0.04807	0.03452	-0.02347	0.60756	-0.03406
0.80944	0.01789	0.24362	0.04791	0.06460	-0.03186	0.62017	-0.03315
0.79683	0.01898	0.23122	0.04767	0.07556	-0.03415	0.65801	-0.03031
0.78422	0.02006	0.21885	0.04736	0.09825	-0.03801	0.67063	-0.02933
0.77160	0.02113	0.20652	0.04696	0.12166	-0.04103	0.68325	-0.02834
0.73374	0.02428	0.15762	0.04434	0.13355	-0.04229	0.69587	-0.02734
0.72112	0.02531	0.14554	0.04338	0.14554	-0.04338	0.72112	-0.02531
0.69587	0.02734	0.13355	0.04229	0.15762	-0.04434	0.73374	-0.02428
0.68325	0.02834	0.12166	0.04103	0.20652	-0.04696	0.77160	-0.02113
0.67063	0.02933	0.09825	0.03801	0.21885	-0.04736	0.78422	-0.02006
0.65801	0.03031	0.07556	0.03415	0.23122	-0.04767	0.79683	-0.01898
0.62017	0.03315	0.06460	0.03186	0.24362	-0.04791	0.80944	-0.01789
0.60756	0.03406	0.03452	0.02347	0.25604	-0.04807	0.82206	-0.01679
0.59495	0.03496	0.02619	0.02030	0.26848	-0.04816	0.84728	-0.01455
0.56975	0.03670	0.01925	0.01718	0.29342	-0.04814	0.88515	-0.01114
0.55715	0.03754	0.01384	0.01430	0.33093	-0.04770	0.89778	-0.00999
0.54455	0.03836	0.00681	0.00956	0.34346	-0.04745	0.92307	-0.00769
0.50678	0.04067	0.00460	0.00763	0.35599	-0.04716	0.93571	-0.00654
0.49420	0.04139	0.00174	0.00435	0.36853	-0.04682	0.94833	-0.00540
0.48162	0.04208	0.00028	0.00161	0.38108	-0.04644	0.96091	-0.00428
0.46904	0.04274	0.00002	0.00038	0.40620	-0.04556	1.00000	0.00070
0.43132	0.04453	0.00000	0.00000	0.43132	-0.04453		

The wing twist is nonlinear; it is specified at 20 intervals from the centerline to the wingtip, in degrees, as shown in table 3. Using the above airfoil coordinates, this twist does not require any compensation for aerodynamic twist relative to the geometric twist.

Table 3. Wing twist distribution.

Wing twist			
0	8.3274	11	7.2592
1	8.5524	12	6.6634
2	8.7259	13	5.9579
3	8.8441	14	5.1362
4	8.9030	15	4.1927
5	8.8984	16	3.1253
6	8.8257	17	1.9394
7	8.6801	18	0.6589
8	8.4565	19	-0.6417
9	8.1492	20	-1.6726
10	7.7522		

The control surfaces are located in the outboard 14 percent of each wing, in the trailing 25 percent of the chord; the round tips are included as part of the control surfaces. The wingspan is 12.3 ft, the wing area is 10.125 ft^2, the centerline chord is 15.75 in., and the wingtip chord is 3.94 in. The wing had 2.5 deg of dihedral.

Table 4. Elliptical spanload and bell spanload comparison of spanload parameters and efficiency factors.

Spanload parameter	Elliptical spanload	Bell spanload
b/2	1.0000	1.2247
Cdi	1.0000	0.8889
e	1.0000	0.8889

This comparison is made using the traditional elliptical spanload as the baseline from which the bell spanload is compared.

In figure 4, three spanloads (blue = -5 deg; red = 0 deg; and green = +5 deg) are plotted showing the effect of sideslip on the area of induced thrust near the wingtips and the resulting effect on yawing moment. The light-green line shows a large area of induced thrust on the left and a small area of induced thrust on the right, which would result in a large right-yawing moment.

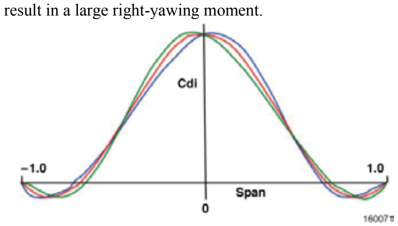

Figure 4. Effect of sideslip on bell spanload with twist (0 and +/- 5 deg).

Aerodynamic Coefficient Estimation

We used Maine and Iliff's output-error approach to estimate the aerodynamic coefficients, which was the same source used for the estimates of Cnda. We assume the aircraft is a continuous-time dynamic system. The process of estimating the aerodynamic coefficients is an exercise in system identification. Assumptions were made in this process, many based on previous experience, such as which parameters were important (these are retained) and which were not (these are ignored). This approach uses a formulation of the solid-body aircraft flight mechanics as a linear simulation of the vehicle. An initial estimate is made of the aerodynamic coefficients; the simulation then makes an estimate of the vehicle motion based on the aerodynamic coefficients, the mass properties, and the equations of motion, after which the linear estimates are compared to the measured flight data from the vehicle. Errors from all of these measurements subject the final estimates of the aerodynamic coefficients to uncertainty. The errors between the simulation output and the measured data are subjected to a measurement based on a weighted error-based cost function defined by the researchers.

The aerodynamic coefficient estimates are then varied, and slopes or gradients are determined numerically from the errors. The estimation program then marches toward minimizing the cost function from the "fit" between the output of the linear simulation and the measured flight data. Maneuvers were simple doublet maneuvers, which are simple square-wave pulses, both positive, followed immediately by a similar pulse of the opposite sign.

The results of the flight research on the small flying wing glider were successful, as can be seen in figure 5(a). We measured proverse yaw in flight for the first time on June 27, 2013. A sample output from the flights shows proverse yaw, as shown in figure 5(b).

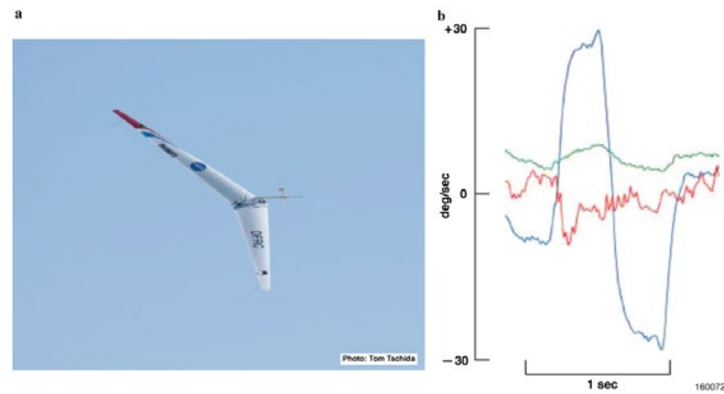

Figure 5. A subscale aircraft in flight, and resulting proverse yaw data trace.

Figure 5(b) shows a data trace of the angular rates from onboard instrumentation. Red is pitch rate, blue is roll rate, and green is yaw rate. The high-frequency motion in pitch rate is due to air turbulence. The yaw motion following the roll motion is the same sign; the yaw gain is 0.0643 and correlation is 0.77 for this maneuver. All rates are to the same scale.

We calculated the coefficient Cnda from the flight research maneuvers. In figure 6, the scattered dots represent the flight research maneuvers. The value of Cnda is positive and the trend of the slope is also positive. The degree of scatter in the data is a result of all experimental error. From this we see that Cnda is providing the yawing moment in the same direction as the rolling moment.

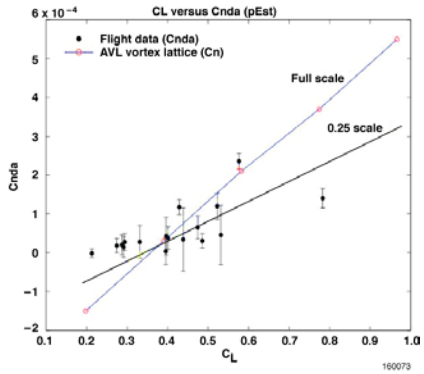

Figure 6. Yawing moment due to aileron deflection coefficient versus lift coefficient.

The yawing moment due to aileron deflection coefficient (Cnda) is shown plotted against lift coefficient in figure 6. The blue line and red circles were predicted for the full-scale aircraft. The black line is an estimate of the 0.25-scale experiment aircraft. The black dots are the estimates from flight data. Error bars are 5x Cramer-Rao bounds. The straight line with the circles represents the analytical data from the vortex lattice. An estimate of the effect of scale is made on the vortex-lattice (reducing the scale reduces the effectiveness of the control deflection and reduces the resulting yawing moment). The good comparison between the predicted and the measured flight Cnda confirmed our expectations regarding Prandtl's bell spanload.

Birds and the Bell Spanload

There are at least two larger implications of this work. The first is for the avian research community; the second is for the aeronautical world.

That birds have no vertical tail yet effect effortless turns remains a puzzle, inasmuch as all avian flight research is analyzed using the elliptical spanload. The matter of formation flight also defies satisfactory explanation despite a century's worth of research, analysis and effort, again in large part because the analysis relies entirely on the elliptical spanload. ("The wake [of the kestrel] was found to be similar to that measured behind an elliptically loaded airfoil of the same span," wrote Geoff Spedding when analyzing his data. "As a result, classical airfoil theory for an elliptically loaded wing was used to calculate parameters such as lift coefficients and efficiency factors" (ref. 11). Less apparent but equally puzzling to close observers is the shape of birds' wings when compared to aircraft wings: the former taper, often to a sharp point, while the latter rarely do, and this, too, defies the elliptical spanload solution. The load distribution over a bird's wing is far more gradual than an elliptical spanload provides: consider a birds' wing

structure—both skeletal and on the surface—which tapers to almost nothing near the tips, where the outermost feathers carry virtually no load at all, as compared to an aircraft's wing. An elliptically loaded aircraft's wings carry loads right to the wingtip.

First, based on our research results we assert that the growing data on bird flight is irreconcilable so long as it relies on the elliptical spanload as the analytical tool. Second, based on the analytical results of the bell spanload and the flight data, we assert the only viable solution for interpreting bird flight, formation flight, and bird wing structure is the bell spanload.

We know that it is a biological imperative that birds carry no excess structure in their wings or chest muscles, only as much as muscle, tendon, and bone as necessary. Birds embody minimum structure while achieving maximum aerodynamic efficiency while accomplishing coordinated flight: birds are a solution to a multivariate optimization. Recall that Prandtl's second paper provided a spanload solution to maximum efficiency for a given structural weight when the wingspan need not be constrained. The bell spanload is the only explanation for how birds achieve this multivariate solution (refs. 12-15).

Birds-Bell Spanload; Airplanes-Elliptical Spanload

1. Birds' primary feathers are soft and flexible at their wingtips and the wings have a narrow chord; these wingtip feathers are incapable of supporting any substantial load. Additionally, the outboard wing structures of birds are long and slender. The ligaments, tendons, supporting muscles, and bones are long and thin, improving aerodynamic performance, but the load-carrying ability of these structures is very modest (the same was true for pterosaurs). In contrast, aircraft wingtip structures are large, heavy, and expected to carry real loads in flight.

2. Birds flying in formation position themselves to capture upwash from a leading bird's wing vortex roll-up for added efficiency. Data shows they do this with wings overlapped. Aircraft flying in formation with similar objectives do not match this profile, however: they fly with wingtips in line.

3. Birds do not experience wingtip stall even with their narrow-chord, sharp-tipped, wings. But when sharp-tipped swept wings are used on aircraft, wingtip stall is common and requires other solutions to overcome.

We are accustomed to seeing birds turn and maneuver without a vertical tail, and only seeing aircraft do so using such drag-inducing devices. The ability to turn and maneuver without resorting to drag-inducing devices to counter adverse yawing forces is the first evidence for why the bell spanload—which generates proverse yaw—explains the flight of birds.

Figure 7 shows a wandering albatross (diomedea exulans) in flight. The wandering albatross has no vertical tail, yet these birds are able to expertly fly so that they precisely touch their wingtips to the water.

Figure 7. Wandering albatross in flight.

Researchers such as Wieselsberger (ref. 16), Lissaman and Schollenberger (ref. 17), and Portugal have argued that flying in formation allows birds to capture upwash in the air from the wing vortex roll-up. There is no dispute that birds maximize the energy from the upwash, something only possible in formation flight. What we dispute is where that vortex occurs on birds. Figure 8(a) shows a formation of pelicans flying with wingtips overlapped, which is an optimal arrangement with the bell spanload but suboptimal for the elliptical spanload because in this case the vortex roll-up is not at the wingtip but inboard of the wingtip (at .704 of the semi-span) and is in fact a wing vortex roll-up, not a wingtip vortex roll-up. Spedding's data support this, as can be seen in figure 8(b); the vortices seen behind his kestrel show a vortex roll-up inboard of the wingtips. ("This wing loading distribution [elliptical] is reflected in the geometry of the wake," he wrote). Birds position themselves in formation flight based on the location of the actual vortex roll-up, and only the bell spanload generates a vortex roll-up in that location.

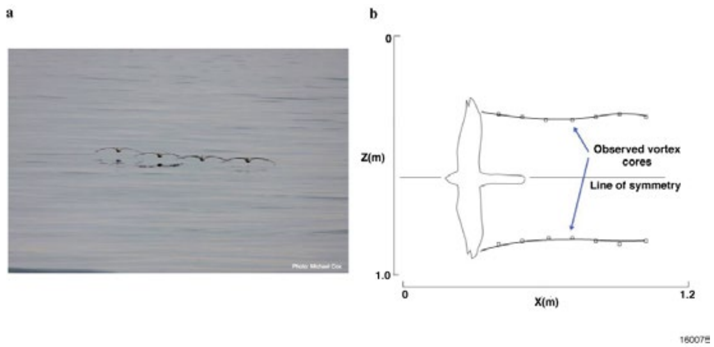

Figure 8. Significant bird flight characteristics; a: Formation flight of brown pelicans (pelecanus occidentalis) demonstrating the resulting wingtip overlap; and b: Spedding's kestrel (falco tinnunculus) data showing an inboard vortex core location.

Figure 9(a) shows spanwise location data of following bird relative to the lead bird in the northern ibis (geronticus eremita) from Portugal, with Hainsworth (ref. 18), Cutts & Speakman (ref. 19), and Speakman & Banks (ref. 20). Figure 9(b) shows an overlay of the data sets with our addition of the downwash curve of the Prandtl 1933 spanload and our extension of Prandtl's 1933 theorum.

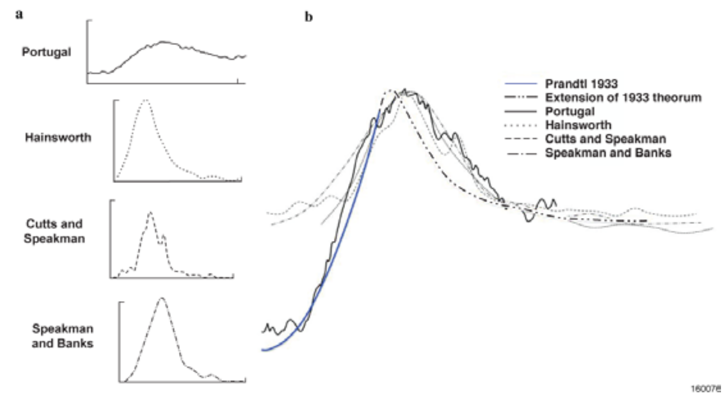

Figure 9. Bird position in formation flight.

Portugal recently published research based on global positioning system data showing northern ibis flying in formation with the tips of their wings overlapping. He concluded that the mean spacing was 0.904 m on a mean wingspan of 1.2 m, for a vortex core separation of 0.753. Spedding gave the vortex core separation of his kestrel research as 0.76 of span. The vortex separation on our research flying wing aircraft occurred at 0.704 of the semispan. Portugal, like Spedding and others before him, analyzed his results using the elliptical spanload, forcing the analysis of the birds to fly formation with their wingtips in line with each other rather than with wings overlapped. Birds in formation flight seek out the greatest upwash, and there is a clear, strong correlation between the location data of birds in formation flight and the vortex formation and upwash data of the bell spanload.

How are birds able to fly with pointed wingtips? Note how the lift tapers gradually to zero at the wingtip with the bell spanload. The result is that even wings with very strongly tapered tips show no tendency to wingtip stall. Rather than occurring at the wingtip (as it will with an elliptical spanload) the stall begins about 20 percent out from the wing root, something observable in the flight of birds [figure 10(b)]. Because the bell spanload creates proverse yaw in the outer third of the wing, the thrust yields controllability even with a sharply tapered wing.

The upwash at the tips of the bell spanload makes it possible to capture the wingtip-induced thrust that can then generate coordinated roll and yaw without resorting to the use of a vertical tail and without generating drag at the wingtips. If we accept Prandtl's 1933 lift distribution as useful for birds, it follows that birds are manipulating thrust at their wingtips to control yaw.

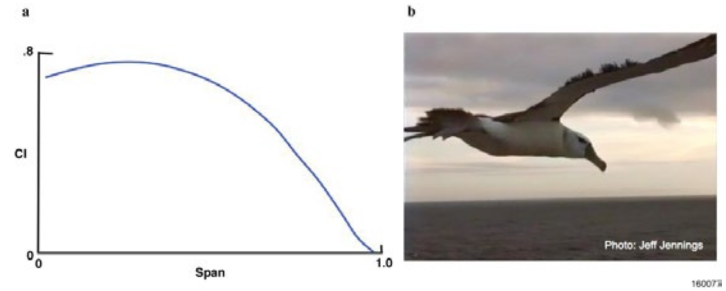

Figure 10. The local lift coefficient (Cl) and the beginning of stall on the wing of a wandering albatross.

Figure 10(a) shows the local lift coefficient as a function of span for a bell spanload from centerline to the wingtip. Note that the highest point on the curve is the area in which the wing would first stall. Figure 10(b) shows an image of a wandering albatross soaring at low speeds (image by Jeff Jennings). Ruffled feathers indicate the beginnings of the stall, at approximately 20 percent of span, not near the tip, matching the bell spanload predictions.

Combining observational evidence and data developed by avian researchers with our own research results, we assert that only the bell spanload provides a coherent paradigm for bird flight. Our research offers for the first time a theory and a tool derived from flight test that satisfactorily explains bird flight to match the data. It also serves as a solution to far more efficient aircraft flight.

Conclusion

The bell spanload maximizes aerodynamic efficiency with a given structure, coordinates the roll-yaw motion so that birds are able to turn and maneuver without a vertical tail, and explains why birds fly in formations with their wingtips overlapped, as well as how birds use narrow wingtips without experiencing tip stall.

The bell spanload also allows for improved aircraft designs, particularly all flying-wing aircraft and blended-wing body aircraft. Even conventional tailed aircraft can benefit from the improved aerodynamics and minimum structure approach. There are circumstances in which span constraints exist (such as extremely large transport category aircraft), in which cases current approaches provide better solutions.

Neither Prandtl nor Horten followed through to the logical and complete conclusion of their work. Prandtl did not extend the upwash outboard of the wingtip, which would have answered the question of formation flight in birds, and he did not find the induced thrust at the outboard ends of the wings, which leads to proverse yaw. In turn, with his approximation and objectives Horten did not understand the origin of the induced thrust at the outboard ends of the wings for proverse yaw, and he did not prove that proverse yaw exists.

It remained for the current authors to prove conclusively that proverse yaw is achievable through an efficient bell-shaped spanload, that an optimal solution integrating minimum structure and minimum drag can solve the problem of yaw control and stability of a flying wing, and that the bell spanload solution answers some of the great enduring mysteries of the flight of birds.

In the case of the flight of birds, the bell spanload is the only viable solution.

References

1. Prandtl L (1921) Applications of modern hydrodynamics to aeronautics, NACA Report No 116 (Washington, DC).
2. Prandtl L (1933) Über tragflügel kleinsten induzierten widerstandes. Zeitschrift für Flugtecknik und Motorluftschiffahrt, 1 VI 1933 (München, Deustchland).
3. Horten R, Selinger P with Scott J (translator) (1985) Nurflugel: The story of Horten flying wings 1933 – 1960. Weishapt Verlag, Graz, Austria.
4. Lee R (2011) Only the wing: Reimar Horten's epic quest to stabilize and control the all-wing aircraft. Smithsonian Institution Scholarly Press, Washington D.C. 312 p.
5. McFarland M (1953) The papers of Wilbur and Orville Wright including the Chanute-Wright letters and other papers of Octave Chanute, vols. 1 and 2.
6. US Patent and Trademark Office (1906) O. & W. Wright, Flying Machine. Patent Number 821,393.
7. Maine RE, Iliff KW (1986) Application of parameter estimation to aircraft stability and control - the output-error approach. NASA RP-1168.
8. Margason RJ, Lamar JE (1971) Vortex-lattice FORTRAN program for estimating subsonic aerodynamic characteristics of complex planforms. NASA TN D-6142.
9. Eppler R, Somers DM (1980) A computer program for the design and analysis of low-speed airfoils. NASA TM-80210.
10. Bowers AH, Sim AG (1984) A comparison of Wortmann airfoil computer-generated lift and drag polars with flight and wind tunnel results. NASA TM-86035.
11. Spedding GR (1987) The wake of a kestrel (falco tinnunculus) in gliding flight. J. Exp. Biol.,127, 45-57.
12. Humphries NE, Weimerskirch H, Queiroz N, Southall EJ, Sims DW (2012) Foraging success of biological Lévy flights recorded in situ. DOI: 10.1073/pnas.1121201109.
13. Sachs G, et al. (2012) Flying at no mechanical energy cost: disclosing the secret of wandering albatrosses. DOI: 10.1371/journal/pone.0041449.
14. Weimerskirch H, et al. (2013) Changes in wind pattern alter albatross distribution and life-history traits. DOI: 10.1126/science.1210270.
15. Portugal SJ et al. (2014) Upwash exploitation and downwash avoidance by flap phasing in ibis formation flight. DOI: 10.1038/nature12939.
16. Wieselsberger C (1914) Beitrag zur Erklärung des Winkelfluges einiger Zugvögel. Zeitschrift für Flugtechnik und Motorluftschiffahrt, 15 VIII 1914 (München, Deustchland).
17. Lissaman PBS, Shollenberger, CA (1970) Formation flight of birds. DOI: 10.1126/science.168.3934.1003.

18. Hainsworth FR (1988) Induced drag savings from ground effect and formation flight in brown pelicans. J. Exp. Biol. 135, 431-444.

19. Cutts CJ, Speakman JR (1994) Energy savings in formation flight of pink footed geese. J. Exp. Biol. 189, 251-261.

20. Speakman JR, Banks D (1998) The function of formations in Greylag geese anser anser; energy saving or orientation? Ibis 140, 280-287.

Tom's Tips

Servo cable restraint

Tom Broeski
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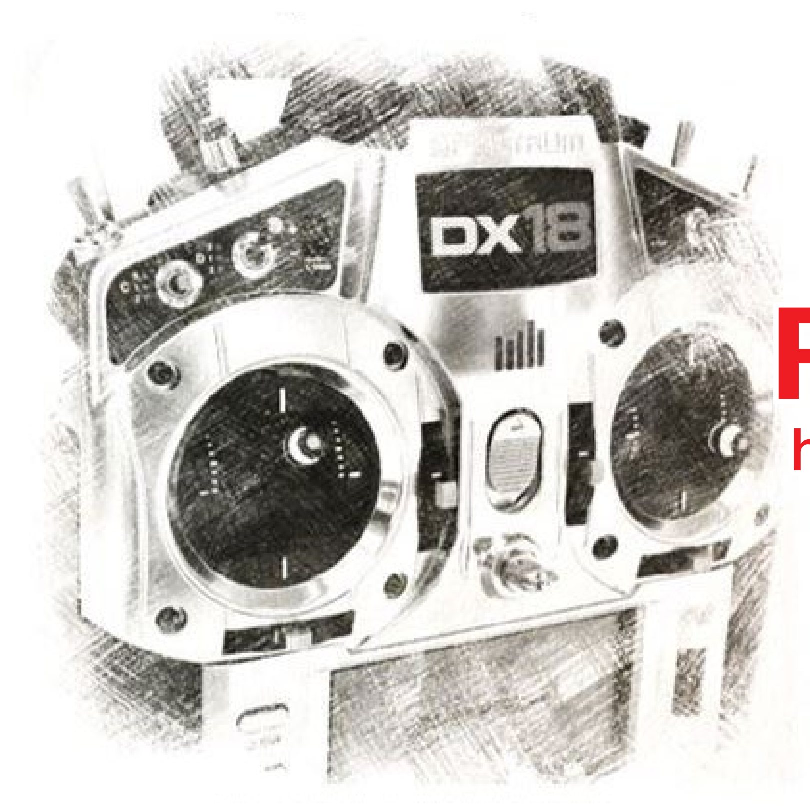
Ever have trouble getting your servo wires out of your wing tip?

This wasn't my idea, but I thought it was worth passing on.

Make yourself some little plastic clips, or use the ones that come on bread products.

That's all... and if you lose one... there are plenty more where that came from.



RED SAILPLANE

https://red-sailplane.myshopify.com/

Sherman Knight, duworm@aol.com

About Red Sailplane

Red Sailplane is owned by Sherman Knight whom has been writing guides and templates for JR and Spektrum RC Radio systems since 1991.

Sherman is a member of the Seattle Area Soaring Society one of the premier RC clubs in the US. SASS is the home of all three of the 2010 junior gold metal winners (gold medal in individual and gold medal in team) of the F3J World Championships in France.

Red Sailplane is dedicated to providing Guides and Templates for sailplanes using Spektrum RC radios, receivers and telemetry sensors, and older JR Radios.

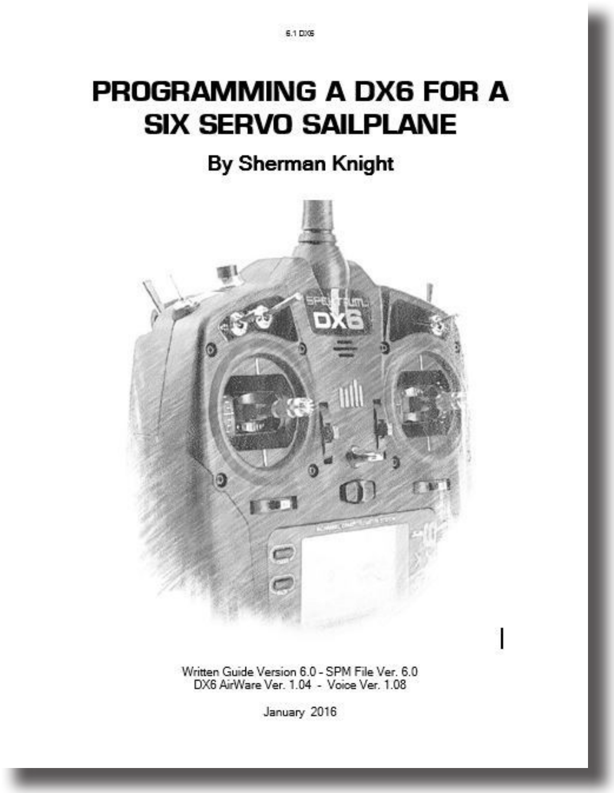
The Red Sailplane catalog

The Red Sailplane catalog currently offers eight transmitter programming PDFs. Here's an outline of what is available:

1. Programming a DX6 for a Six Servo Sailplane
2. Programming the DX6 G2 for the Radian Pro
3. Programming a DX7 for a Six Servo Sailplane
4. Programming a DX9 for a Six Servo Sailplane with a Motor
Programming a DX18 G2 for a Six Servo Sailplane
5. Programming the DX 18 G2 for a Six Servo Sailplane with a Motor
7. Programming the DX8 G1 for a Radian Pro
8. Programming a DX9 for a Six Servo Sailplane

All of these are available at the same price — US$25.95

Here's a brief overview of "Programming a DX6 for a Six Servo Sailplane" and "Programming the DX 18 G2 for a Six Servo Sailplane with a Motor":


6.1 DX6

PROGRAMMING A DX6 FOR A SIX SERVO SAILPLANE

By Sherman Knight

Written Guide Version 6.0 - SPM File Ver. 6.0
DX6 AirWare Ver. 1.04 - Voice Ver. 1.08

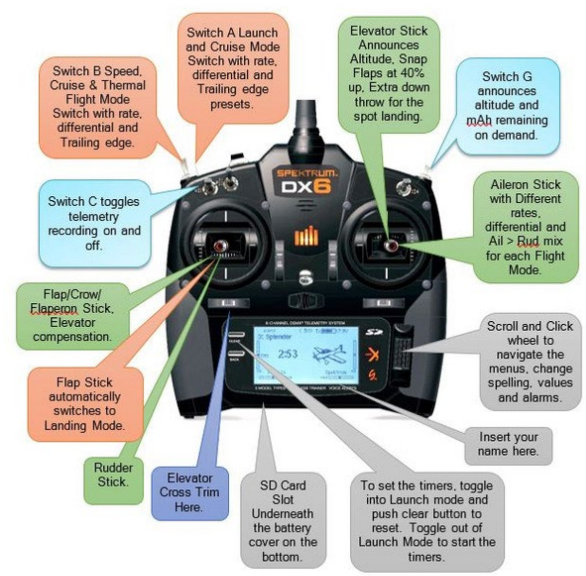
January 2016

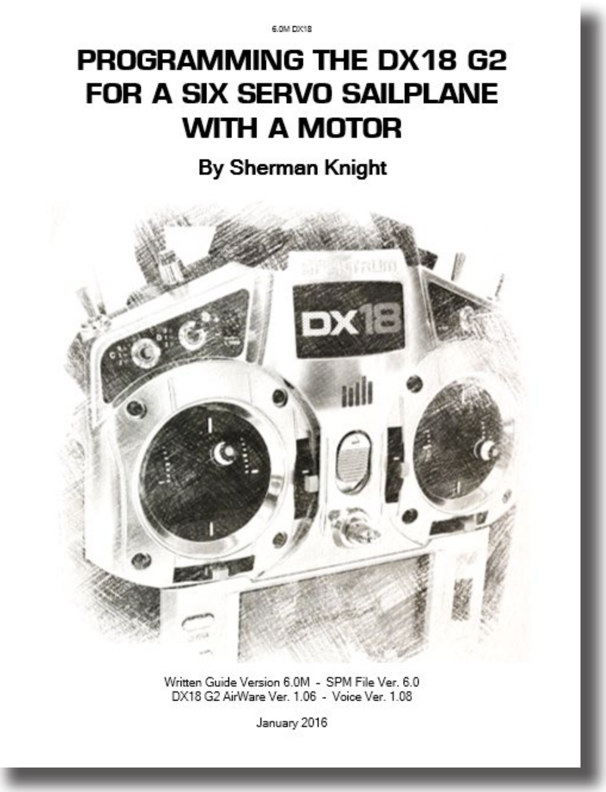
The Guide and Template, "Programming a DX6 for a Six Servo Sailplane," provides everything you need. The bundle includes a 71 page guide, three SPM templates for different wing servo configurations, and a check list at the end on how to setup your own plane from scratch.

If you want to use telemetry, the guide also shows you how to setup it up.

In addition the guide includes the following.

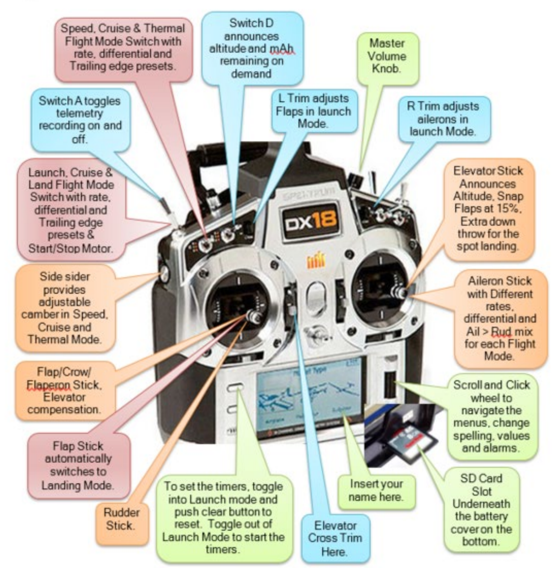
1. Five Flight Modes with appropriate changes in Rates for Ailerons, Elevator and Rudder.
2. Other active mixes include; Aileron to Rudder Mix, Aileron to Flap Mix, Aileron and Flap Differential and Snap Flaps for each of the Five Flight Modes.
3. Trailing Edge presets for each flight mode.
4. How to change the three types of trim settings.
5. How to cross trim the Elevator.
6. How to change the power up warnings.
7. How to set up the mechanicals before you start programming.
8. Automatically toggle into Landing Mode when Flap Stick is pulled below 92%
9. Flap > Elevator Compensation with Crow or Flaperons for Landing Mode.
10. Two dedicated Timers with Voice count down.
11. Voice announcement for all Flight Modes.
12. Automatic Voice announcement of altitude at top of the zoom.
13. Telemetry voices for altitude, current left in the receiver battery, and Telemetry recording.
14. Addendum for V-Tail and how to use the Monitor for troubleshooting.
15. Voices for Sailplane organized in their own group.
16. Templates for three different types of wing servo setups.
17. Setting the Center of Gravity.
18. Three page cheat sheet for programming a blank template.





The Guide and Template, "Programming the DX18 for a Six Servo Sailplane with a Motor," includes:

1. Five Flight Modes with appropriate changes in Rates for Ailerons, Elevator and Rudder, Differential for both Ailerons and Flaps, Aileron > Rudder Mix, Aileron to Flap Mix and Snap Flaps for each of the Five Flight Modes.
2. How to change the power up warnings that keep your flaps from slamming into the ground at startup.
3. How to change the three types of trim settings.
4. How to cross trim the Elevator.
5. How to set up the mechanicals before you start programming.
6. Trailing edge presets for each Flight Mode.
7. Left Side Slider cambers the trailing edge in all flight modes except for Launch Mode.
8. Automatically toggle into Landing Mode when Flap Stick is pulled below 92%.
9. Flap > Elevator Compensation with Crow or Flaperons for Landing Mode.
10. Motor ON/OFF using the Launch Mode Switch.
11. Virtual Motor soft start.
12. Throttle cut announced with voices.
13. Two Timers, one that tracks total motor run time and a second that tracks total time aloft.
14. Voice announcement for all Flight Modes.
15. Automatic Voice announcement of altitude at top of the climb.
16. Switches that announce altitude, current left in the receiver battery, and Telemetry recording.
17. Voices for Sailplane organized in their own group.
18. Setting the Center of Gravity.
19. V-Tail mixing explained with setup guidelines.
20. Trouble shooting with the Monitor
21. Three page cheat sheet for programming a blank template.



Using XFLR5 v6

and learning a lot

Anker Berg-Sonne, bostonsearover@gmail.com

XFLR is a very powerful tool for RC glider design, but it comes with a hefty learning curve that is exasperated by crashes when the data you enter hits boundary conditions. But once you learn how to run it and interpret the results it is an invaluable tool.

I had several false starts with it until I recently managed to figure out the essentials.

In this article I will start with a simple tutorial that hopefully will get you through the learning curve quickly.

After that I will show you some of the useful insights you may gain from its use.

Caveat

I am not an aeronautical engineer, so some of the explanation and conclusions I have made may be incorrectly stated or just plain wrong. If this happens I encourage someone with a better understanding to jump in and correct me.

Installing XFLR5

Download XFLR5 from <https://sourceforge.net/projects/xflr5/files/>. The file is a zip file, not a windows installation file. Unzip it into a folder and create a link on your desktop to the exe file (right click on it and send it to the desktop). This works for Windows. XFLR5 v6 is also available for Macintosh OS X and Linux.

Running XFLR5

When you click on the desktop icon you created XFLR5 will start and present you with a blank page. This is where a lot of users get lost. If you click on File/New Project, nothing changes. The key selections are File/XFoil Direct Analysis and File/Wing and Plane Design.

You start with XFoil Direct Analysis to load or create the airfoils used, and after that you define and analyze a plane in Wing and Plane Design.

Before you do this, go to Options/Units and set your units. I use inches for lengths, square feet for area, mph for speed, oz for mass, lbf for force, and lbf. ft. for moments.

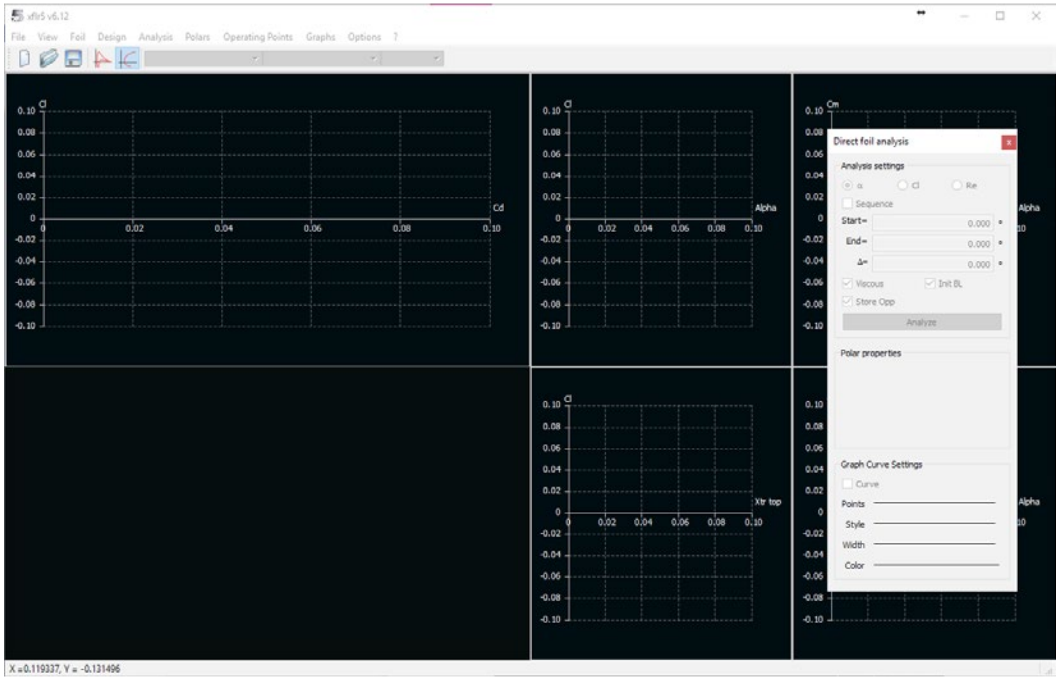
XFoil Direct Analysis

After you select XFoil Direct Analysis you get an intimidating display similar to the what is shown in Screen 1.

It's not clear at all what the next step is. But I am here to help. Click on the

icon and you will get a dialog box prompting you to load a file. One of the options is a Donovan/Selig formatted .dat airfoil file. Once you have it loaded you have the same dilemma as before.

Nothing changed, except the airfoil name will show up in a dropdown list on the icon bar, and there's no clue to what you should do next. Again, Anker to the rescue.



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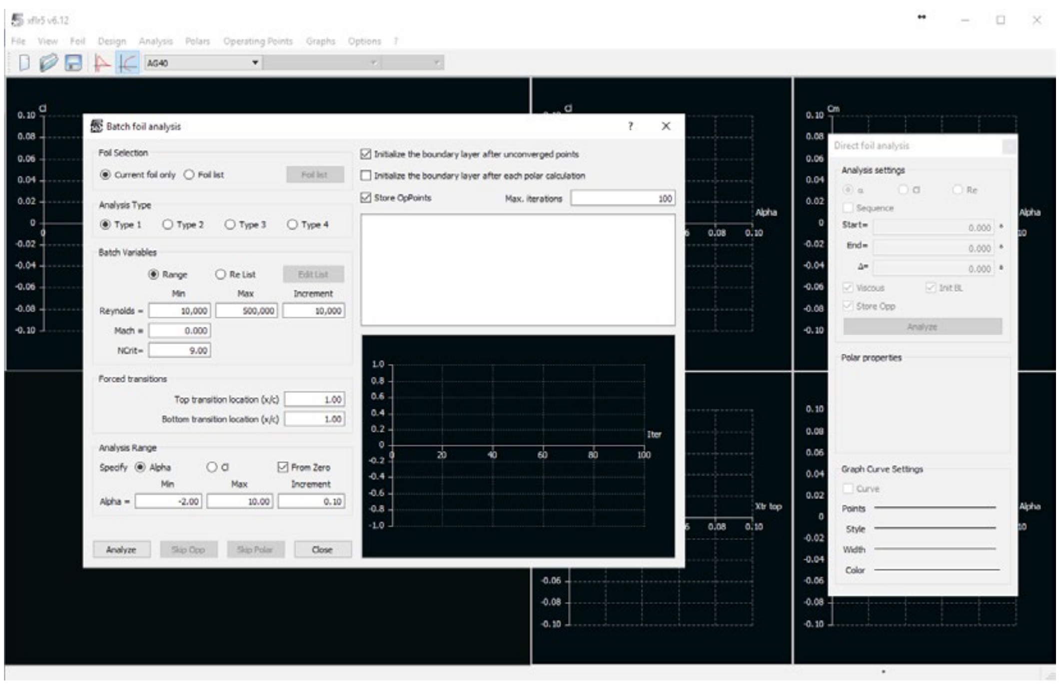

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Click on Analysis/Batch Analysis and you will get a dialog box with a whole bunch of input fields.

See Screen 2.

Here's how I suggest you set up the parameters:

Leave the Analysis Type as Type 1.

Enter reasonable numbers in the Reynolds Min, Max and Increment fields. I have a fast laptop, so I select 10,000 as the minimum, 500,000 as the maximum and 10,000 as the increment.

Next select a range of Alpha values (angles of attack) for the analysis.

For a wing profile I typically choose -2 as the minimum, 10 as the maximum and 0.10 as the increment.

I also check From Zero and Initialize the boundary layer after each polar calculation. I find that checking these boxes eliminates some spurious values.

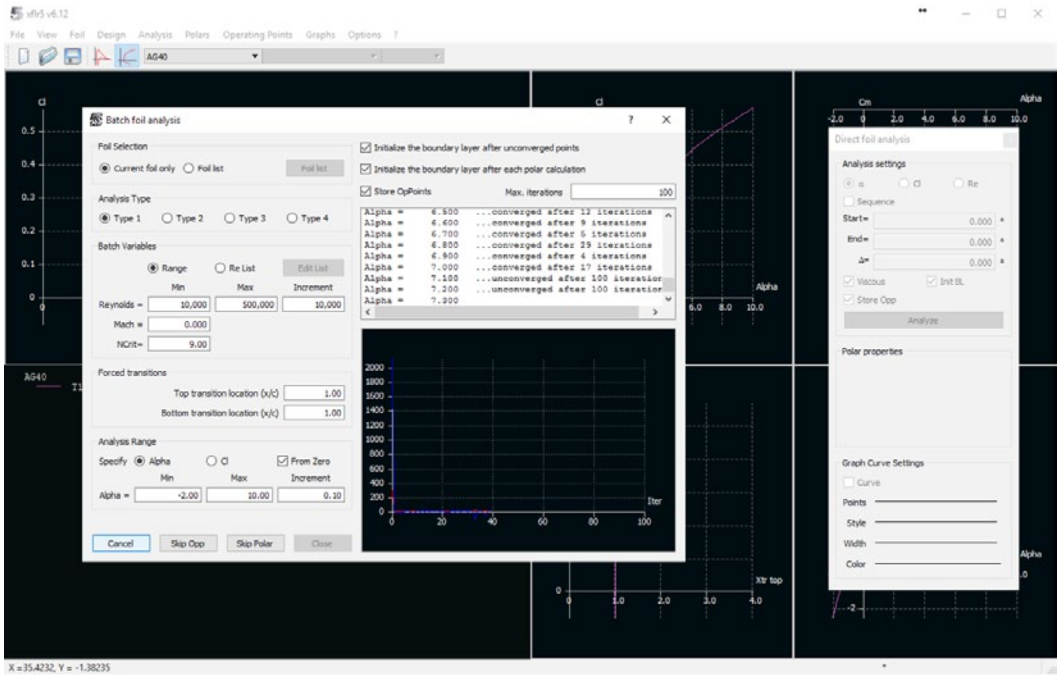
Now you are ready to analyze the airfoil using the built-in XFoil routines.

Click on Analyze. The display will get very busy.

The dialog box will show output from XFoil and various polars will show up in the graphs on the main display.

See Screen 3

The program may also crash and cause you to lose all data entered or calculated since the initial load. So before you click



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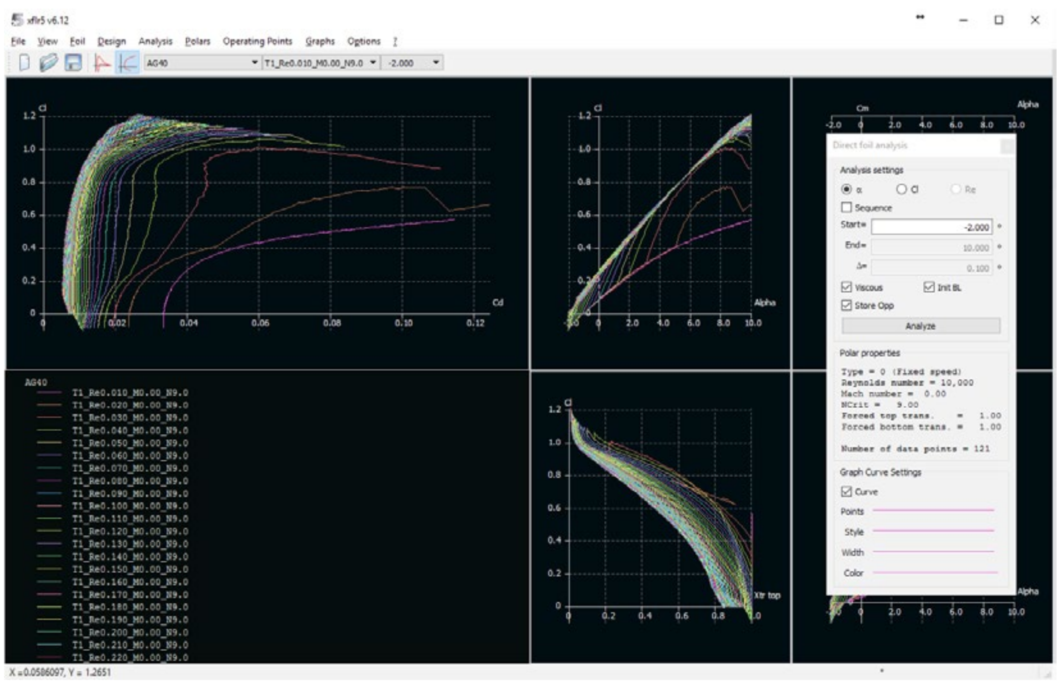

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Analyze it's a good idea to save the project by clicking on the icon and selecting a location and file name for your project.

If it crashes, reload the project and narrow down the Alpha and/or Reynolds number ranges. You probably ran into some boundary condition that XFoil can't handle.

If it doesn't crash you will something similar to what's shown in Screen 4.

I loaded the Supra airfoils from the Charles River Radio Controllers web site.

The wing profiles are all reflexed 2 degrees, so we need to create and analyze airfoils that have all of the camber settings we plan to look at. I'll define one cambered 0 degrees for cruise and one cambered 3 degrees for thermal mode.

To do this select one of the airfoils in the dropdown list on the icon bar.

The first thing I do is to rename the current airfoil so the name reflects the flight mode it represents. Do this by selecting Foil/Current Foil/Rename and giving it the appropriate name, in my case AG40 Reflex.

To create a cruise mode airfoil select Design/Set Flap and then select T.E. Flap and enter 2 in Flap Angle and 75 in Hinge X Position. Don't worry about Hinge Y Position.

Click OK and change the name to an appropriate one. In my case AG40 Cruise and click OK.

Keep doing this until you have all your camber positions defined. You can either analyze the airfoils one at a time or as a batch at the end, but don't forget to save the project before each analysis.

You do a batch analysis just like a single airfoil analysis, but check Foil List and click on the Foil List button to select all of the foils you want to analyze with the same parameters.

I do not recommend doing a Multi-threaded Batch Analysis. I have had too many problems with that.

Now we are on a roll.

Keep loading airfoils used in your plane and analyze them. For stabs and fins I recommend Alpha ranges of -6 to 6.

Once all of the airfoils have been loaded and analyzed we are ready to define a plane.

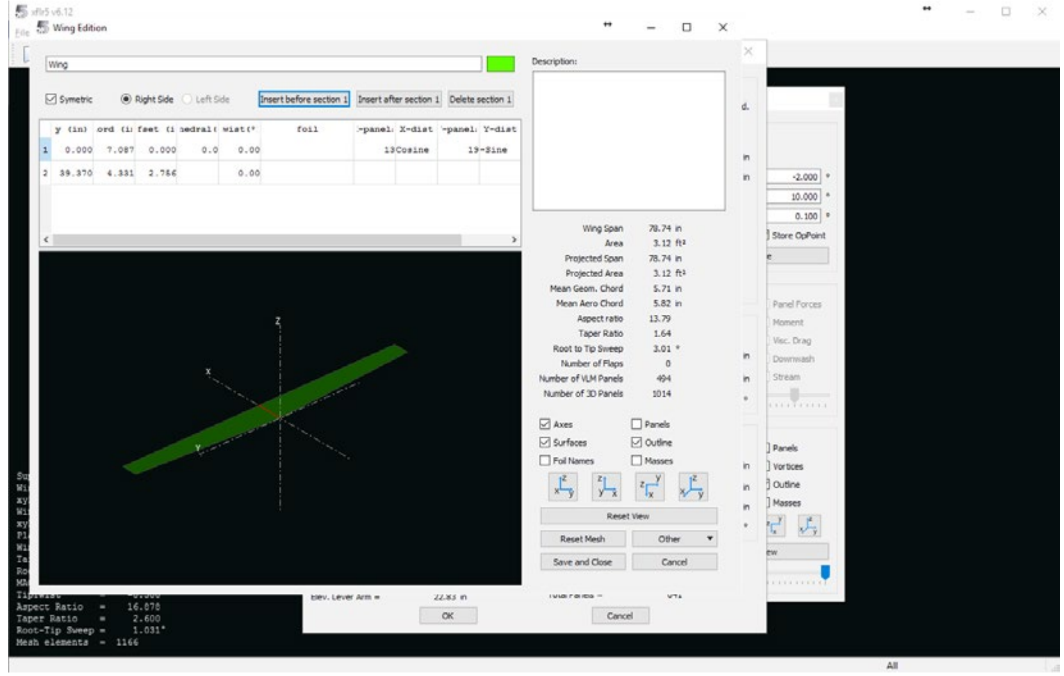
Wing and Plane Design

For this article I have loaded all the Supra airfoils and will define a Supra plane.

Select File/Wing and Plane Design and then select Plane/Define a New Plane.

Start by giving the plane a name. Choose one that is meaningful and descriptive. For example, Supra Reflex.

5



Each flight mode is set up as a different plane. I recommend doing this so you can compare polars across flight modes.

Then click on Define under Main Wing. The dialog box that show up will have a line in it for each panel.

See Screen 5.

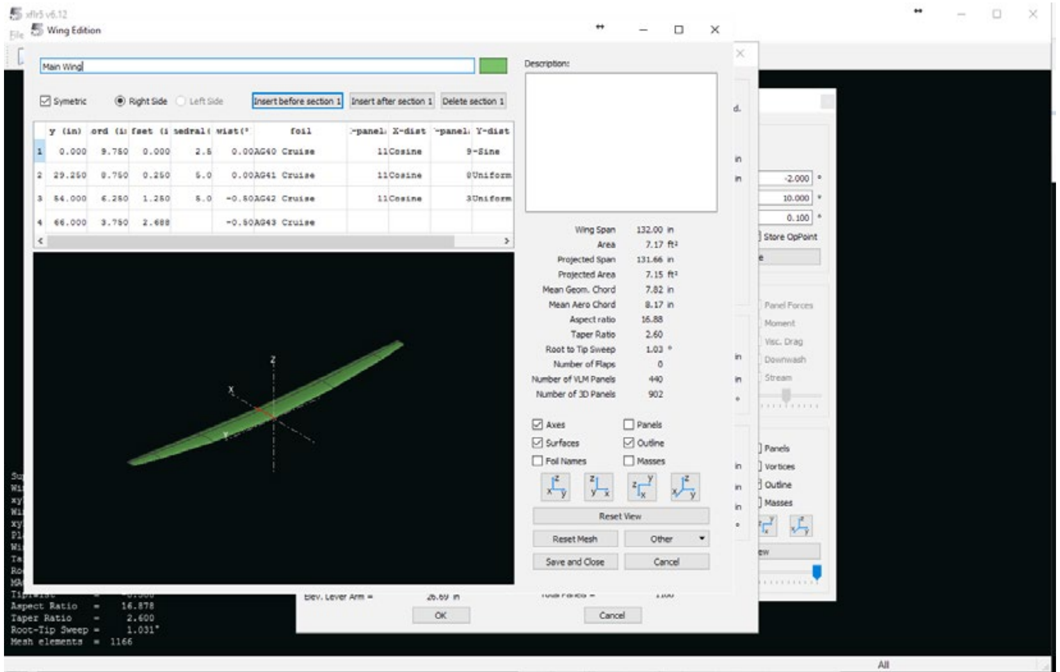
Starting with the first line, define the center panel, with the span position (the first field) 0, the chord at the center and 0 as the offset.

Enter the dihedral (relative to the horizontal, which for the Supra is 2.5 degrees), the twist (0 for the root of the center panel), and then click on Foil to select the airfoil.

Now move to the next line that defines the tip of the center panel and the root of the tip panel.

After that click on Insert After Section 2 and enter the data for the tip of the inner tip panel and the root of the outer tip panel. All data is relative to the root and front of the center panel.

Click on Insert After Section 3 and enter the data for the tip of the outer tip panel.



6

The data for the fully defined Supra wing is as is shown in Scrren 6.

Click on Reset Mesh. This ensures that the analysis will operate on well-structured wings elements.

Then Save and Close.

Proceed to defining the stab and fin planforms.

Next set the airfoil positions and angles relative to the plane axis.

For the Supra I set the wing tilt angle at 2 degrees, the elevator X position at 28" and Z position at 2", and the fin X position at 33".

We are almost done, but have to set the CG at the correct position.

I have it at 40% of the root chord, 3.8" from the LE.

This is a little tricky. To get a decent simulation you have to have realistic moments and then you have to add the right amount of ballast in the right position to get the correct mass and CG.

To do this, click on Plane Inertia.

In the Plane Inertia dialog box start by clicking on Main Wing and enter the wing mass in the WingMass field. For the Supra I enter 28 oz.

Click OK and do the same for the stab and fin.

For these I enter 3 and 4 oz. The result of entering these values is that the combined weight is 35 oz and the combined CG is at 9.723".

A realistic flying weight for a Supra is 62 oz., at a CG of 3.8" behind the LE.

So we have to add 27 oz. of ballast, but where?

To calculate the position, consider that the moments of the combined airfoils and the ballast be equal and opposite around the desired CG.

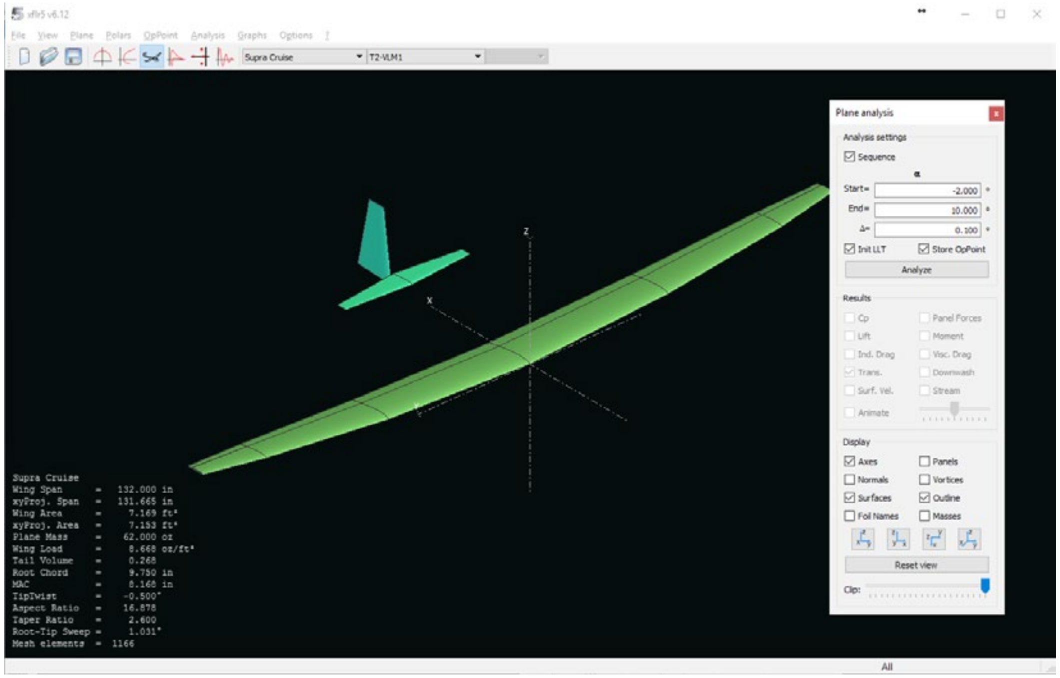
So 35 * (9.733 - 3.8) = 27 * (3.8 - BP) where BP is the ballast position.

Reducing this 207.655 =1 02.6 -27 * BP, or BP = -105.055 / 27, resulting in BP = -3.891.

Enter 27 into the mass field on the first line of the Additional Point Masses field and -3.891 into the X position.

Lo and behold, the mass of the plane is now 62 oz with a CG at 3.8" behind the wing LE.

After all of this, try to click on the plane icon and you should see an image of the plane and a list of the various measures for it.



7

For the Supra I have what's shown in Screen 7.

You probably also want to analyze the plane with different cambers.

Do this by selecting Plane/Current Plane/Duplicate, give the new plane a meaningful name, like Supra Reflex, and click OK.

Then click on Plane/Current Plane/Edit Wing, and change the airfoils in the list of panels and finally Save and Close. Easy!

When you have defined planes for all the camber positions desired it is finally time to do some analysis.

Analyzing plane performance

For each plane configuration you need to start by clicking on Analysis/Define an Analysis and make sure Type 2 (Fixed Lift) is selected, click OK and then fill out the dialog box that has annoyingly hovered over your main window.

If you closed it you can bring it back by clicking on File/Wing and Plane Design.

Check Sequence and enter the Alpha values you used to analyze the wing airfoils with into Start, End and Delta.

Then click on Analyze.

A popup window with a log and a progress bar will appear.

When the analysis is completed you will most likely be told that there were some errors. Don't worry about these. They happened at the boundary condition and will not affect the results.

Now click on the  icon and then select Graphs/All Graphs.

You will see a bunch of polars. These may not be meaningful to you. The ones I like to look at aren't in the default list.

To change a graph double click on it and a dialog box will pop up.

I like to look at the following two: Vz vs V and CL/CD vs V.

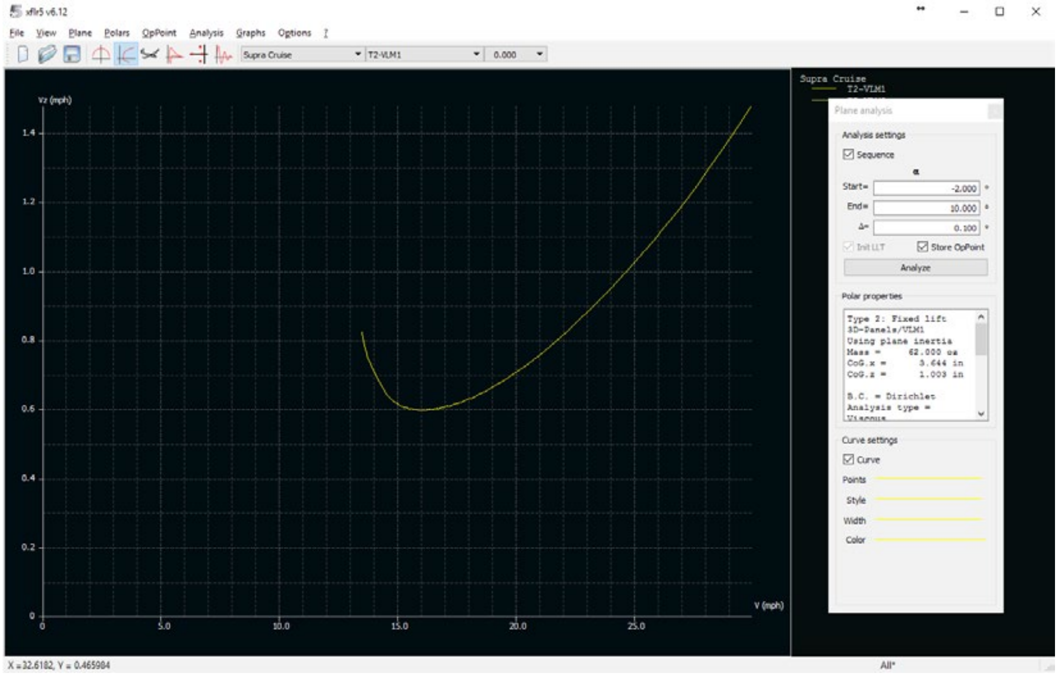
The first one shows sink speed at different air speeds with minimum sink at the minimum of the graph.

The second graph shows you the speed at which your still air glide ratio is optimal, at the maximum of the graph.

You really only need the first graph to determine both.

To do this, click on Graphs/Graph <n> where <n> is the graph showing Vz vs V. This fills the window with just the one graph. Like the one shown in Screen 8

If you want to change the color of the graph double click on the Color line in the Analysis Settings dialog box and select a better one from the color chart.



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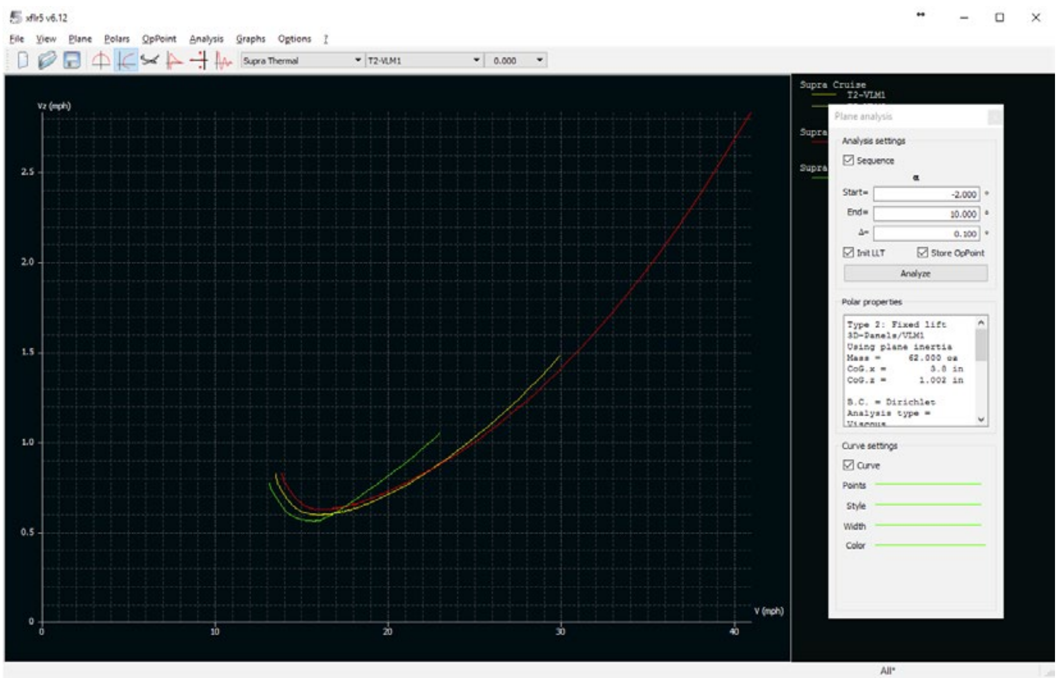


9

I like to use green for thermal, yellow for cruise and red for reflex modes.

If you hover the cursor over the minimum of the graph you can read the X and Y coordinates from the lower left of the window.

It tells me that the Supra in cruise mode has a minimum sink of 0.56 mph when flying at an airspeed of 15.7 mph in cruise mode.

Your actual plane will not be able to perform at this level because we haven't included the fuselage drag and the assumption is that all airfoils are perfect with no servo horns, no control surface slots, etc.

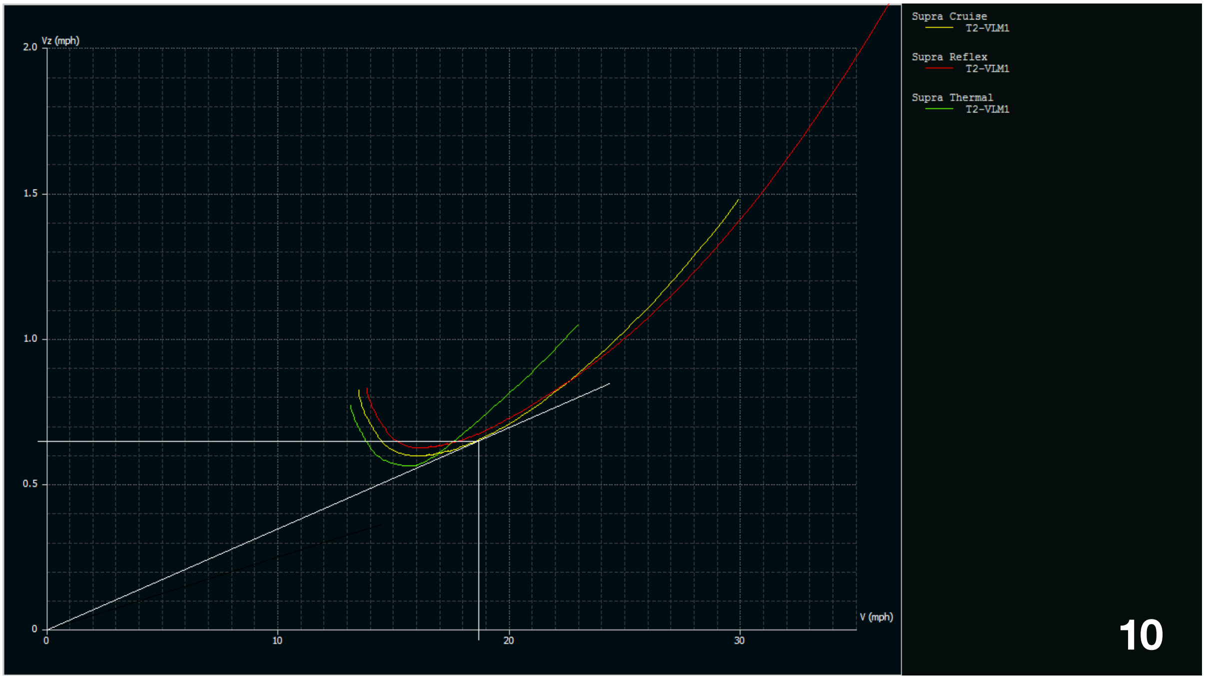
The airspeed at minimum sink quite accurate while the actual sink rate is optimistic.

If you select another plane and analyze it, the polars will be overlaid.

You can control what polars are shown by selecting Plane/Current Plane/Show Associated Polars and Plane/Current Plane/Hide Associated Polars.

For this analysis we will overlay the three flight modes with one another. In Screen 9 I have the polars for the Supra in Thermal, Cruise and Reflex

Not surprisingly, the best sink rate is in thermal mode at 0.56 mph and an air speed of 15.8 mph, followed by cruise and then reflex.



The bottom of the thermal mode curve is nice and flat, giving you a speed range from 14.5 to 16.5 mph with little penalty for deviating from the optimum at 15.5 mph. This is one of the reasons why the Supra is so easy to fly.

Really interesting is a glide ratio (or L/D) analysis. To perform this it is easiest to save the graph as an image by right clicking on it and selecting Save View to Image File, and then opening the saved image in Paint.

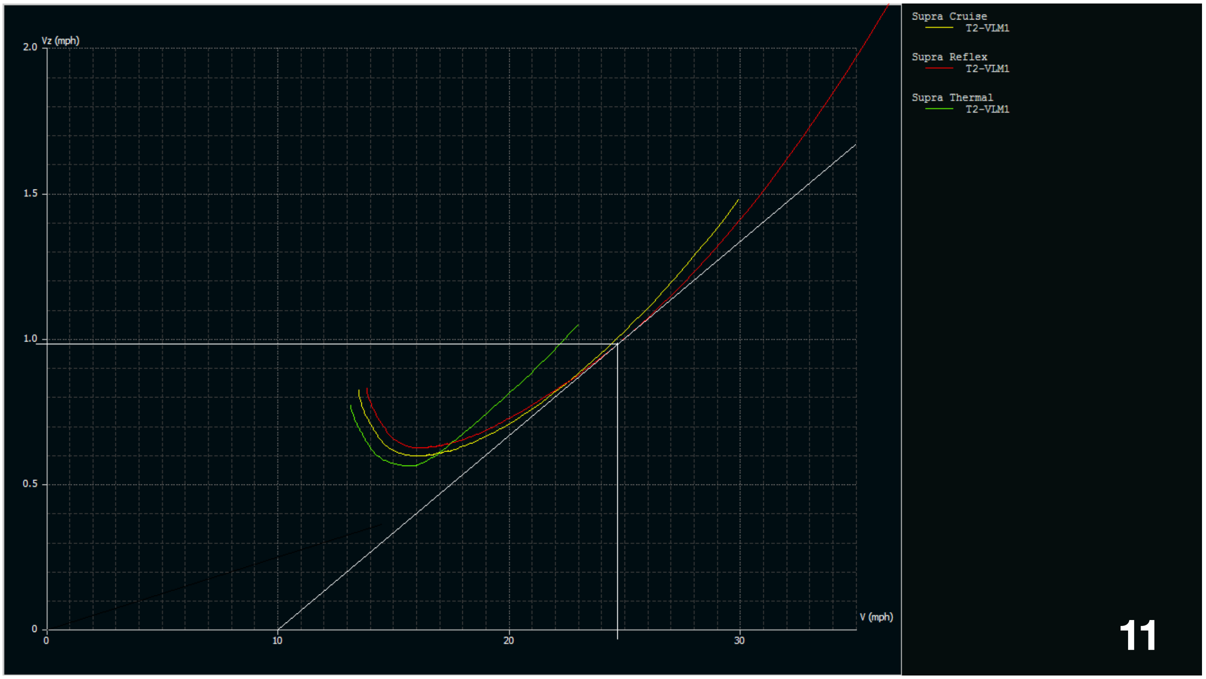
To find the best glide ratio over the ground at a given wind speed against the plane, draw a line from the value of the headwind that just touches one of the graphs and then read the airspeed and sink speeds from that point.

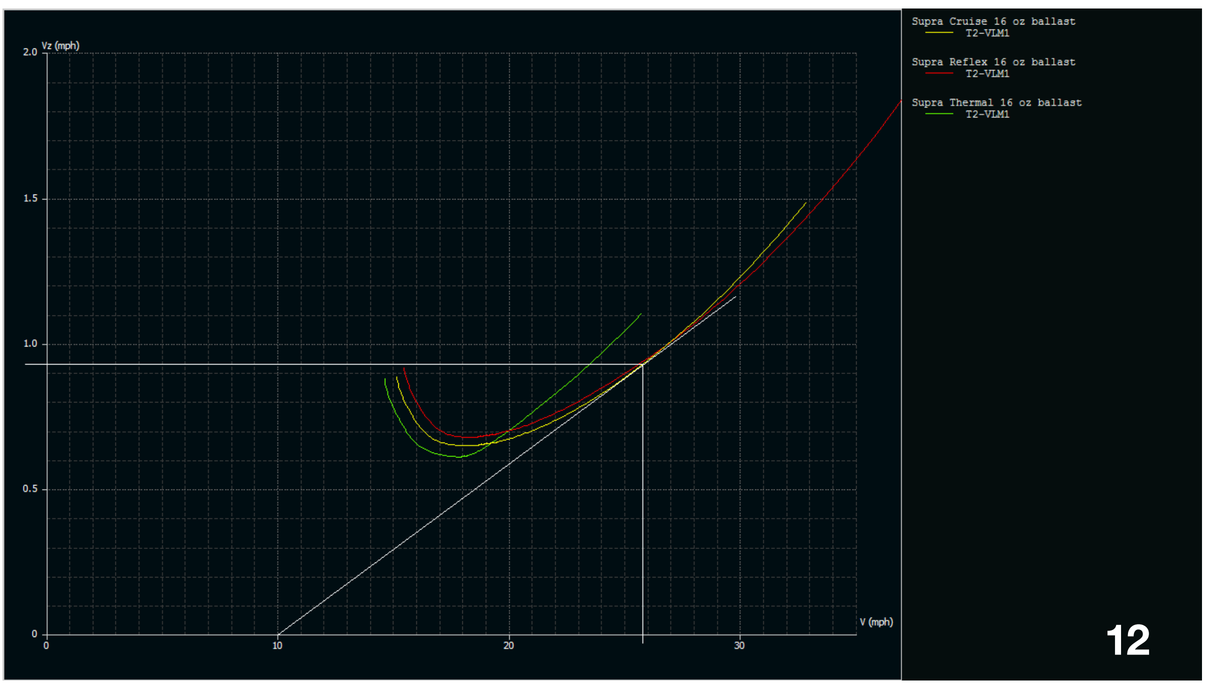
The following graph (Scrren 10) shows the best glide ratio in still air. Note that I have rescaled the graph and added minor grids to make it easier to read data off it. This is done by double clicking on the graphs and selecting the Scales and Axis and Grids tabs.

To draw the lines in Paint choose the line tool, select the thinnest line in the Size list and double click on the white square in the Colors selection. Then draw lines by dragging the cursor.

The best glide ratio in still air happens in cruise mode at an air speed of 18.8 mph and a sink speed of 0.66 mph, resulting in a glide ratio of 18.8/0.65 or 28.48.

XFLR5 is an incredibly powerful program and with this simple introduction to it you should be able to explore many more options, like changing the airfoils, aspect ratios, or tail moments.





Let's look at a head wind of 10 mph, as shown in Screen 11.

The best glide ratio now happens in reflex mode at an air speed of 24.2 mph and a sink speed of 0.98 mph. The ground speed is 14.2 mph resulting in a glide ratio over the ground of 14.2/0.98 or 14.5. Quite a dramatic drop from the still air glide ratio.

So let's add some ballast. For example 16 oz.

To do this, take each defined plane, create a new plane by selecting Plane/Current Plane/Duplicate and giving the plane a reasonable name before saving it.

Then select Plane/Current Plane/Define Inertia and add ballast and adjust the CG so it's back where it belongs.

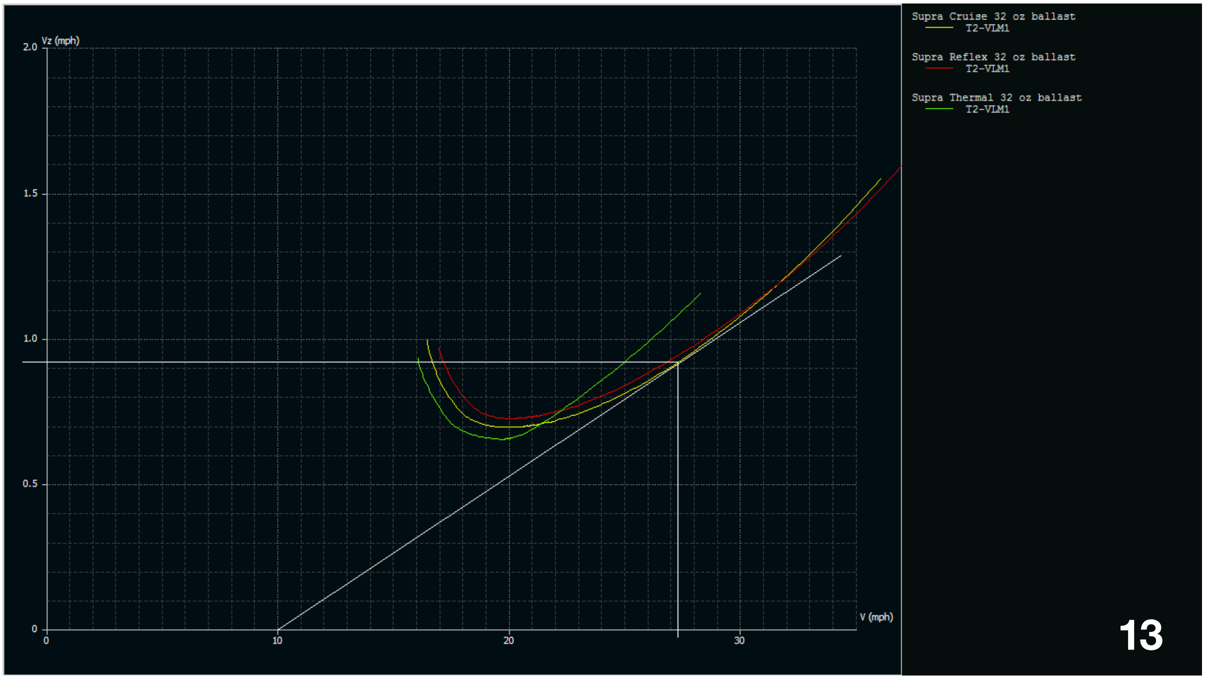
Do an Analysis/Define an Analysis and then Analyze each of the planes and remember to remove the graphs from the un-ballasted planes.

Then save the graph and perform the same glide ration analysis as before in Paint.

See Screen 12

The best glide ratio now happens at 25.9 mph and a sink rate of 0.93 mph resulting in a glide ratio of 17.0 over the ground.

The glide ratio has improved and surprise, surprise, its best in cruise mode!



If you decide to do your own plane design, a program like XFLR5 is essential.

This has happened at the expense of minimum sink, which is now 0.611 mph at 17.8 mph. This is not as dramatic a change as I had expected, so let's add another pound of ballast.

See Screen 13

The best glide ratio is now at an airspeed of 27.25 mph and a sink rate of 0.92, still in cruise mode, giving a glide ratio of 18.75 over the ground. This is a further improvement.

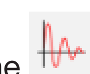
And the minimum sink is 0.66 mph at an air speed of 19.6 mph. A surprisingly small improvement at a surprisingly small penalty, at least to me.

What has really changed are the speeds. The best glide ratio airspeed has gone from 24.2 to 25.9 to 27.25 mph.

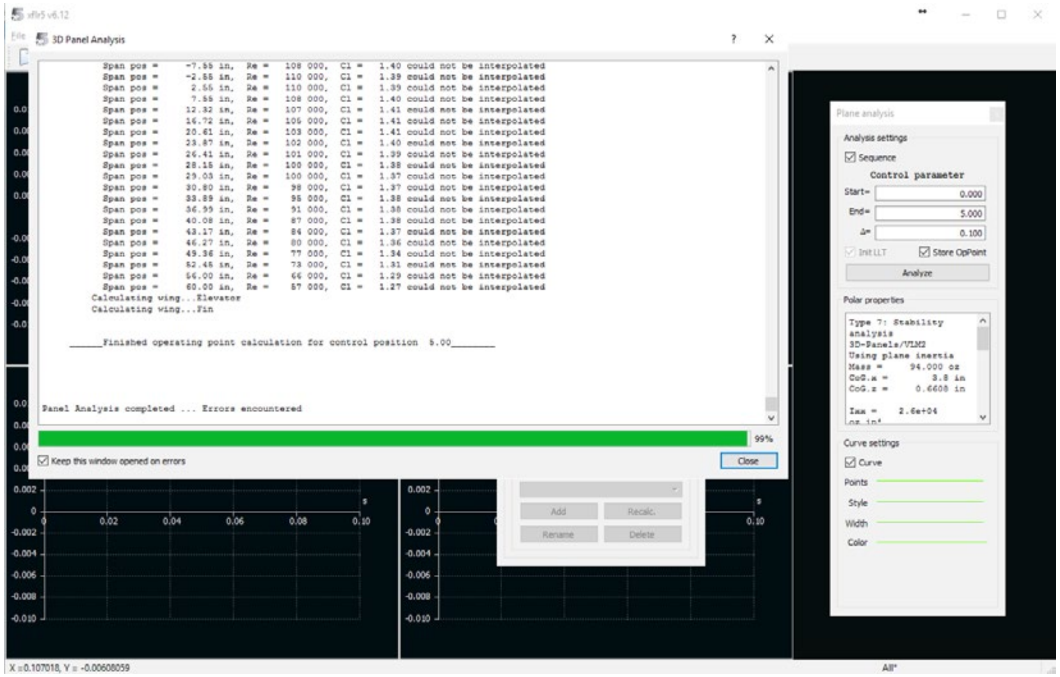
If you do the sink speed analysis for tail winds you will see that all the best glide ratios happen in thermal mode!

The next analysis we will do is a stability analysis to figure out where the CG of the plane should be.

You need to be in Wing and Plane design.

Click on the  icon in the icon bar and a Stability dialog box will pop up in addition to the Plane analysis one.

Click on Analysis/Define a Stability Analysis, make sure Mix 3D Panels/VLM2 and Viscous Analysis are checked and



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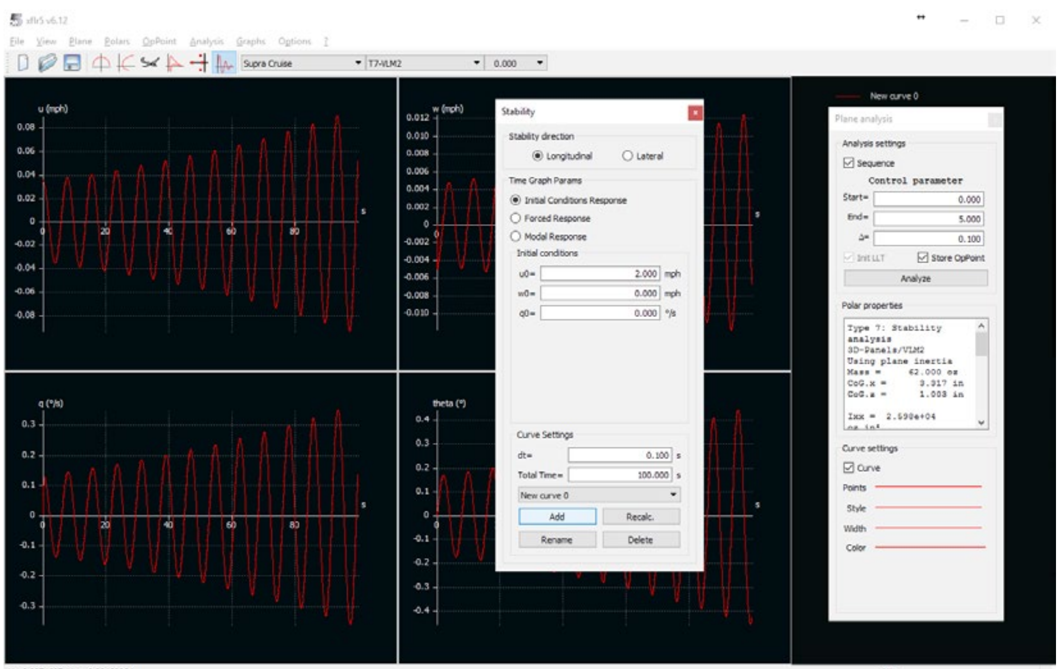


15

click OK. Then click Analyze in the Plane analysis dialog box.

You will see a log window pop up.

If the pop up display stops with "Panel Analysis completed ... Errors encountered" you probably have your CG too far back.

See Screen 14.

If this happens click Plane/Current Plane/ Define Inertia and move the CG forward, and click the Analyze button again.

If the analysis succeeds, the log dialog box will close by itself and you will see that the Add button in the Stability dialog box isn't greyed out any more.

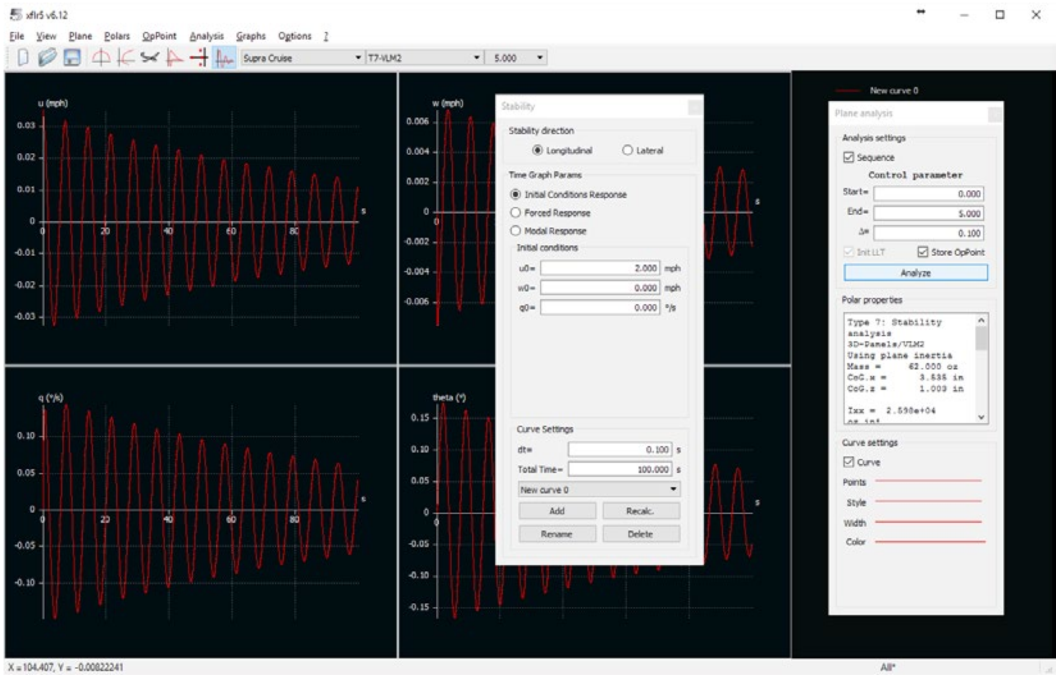
To see the results of your analysis enter a value in the u0 field. This is a vertical perturbation in mph. Use some small value like 2, and then click Add.

You should see a graph show up in the main display. If you don't see several cycles in the graph, double click on it and change the X scale.

You will see something similar to what's shown in Screen 15.

If the amplitudes increase as in the graph just shown the plane is porpoising because the CG is too far forward, so we need to move it back and repeat the analysis.

Keep doing this until you see a graph where the amplitudes decrease over time, like in Screen 16.



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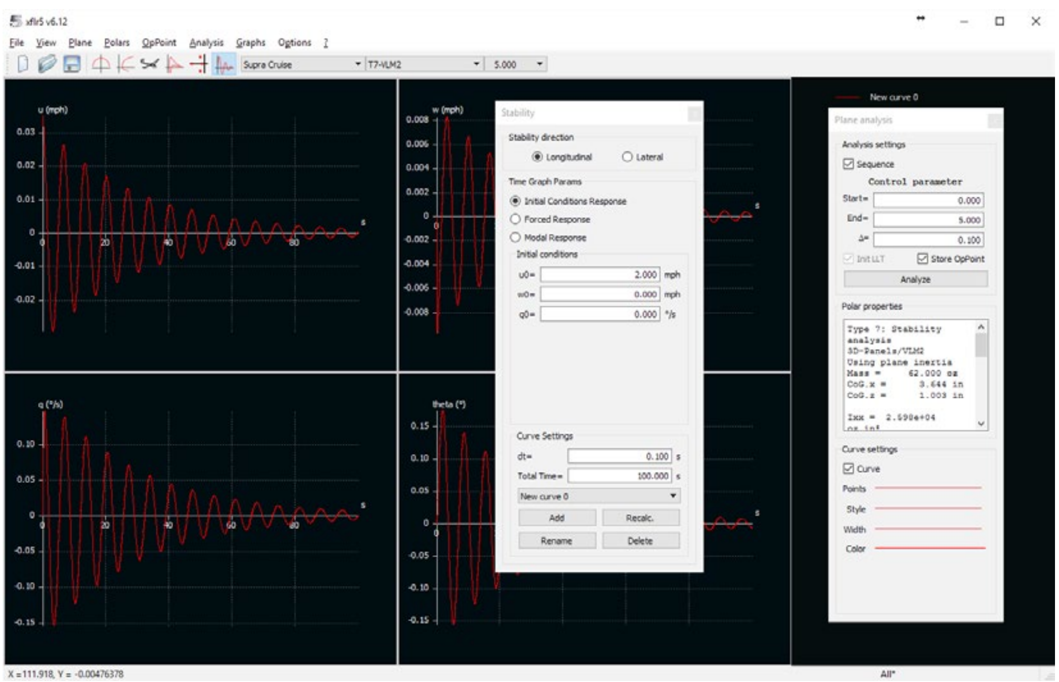


17

The decreasing amplitude shows that the plane will recover from a perturbation and return to level, stable flight hands off. Progressively moving the CG back will reduce the time to recover to stable flight, as shiown in Screen 17.

Eventually the analysis will fail, indicating that the plane has become unstable again because of a too far backward CG.

Wrapping up

Once you have figured out how to run XFLR5 there's a lot of interesting stuff you can do, and very easily. You may also be surprised at the results.

I, for one, discovered that the penalties for ballasting are surprisingly small, as are the results; and to achieve them, you need to carefully manage your air speeds. I have decided to add air speed telemetry to my TD planes.

I was also surprised to learn that reflex mode isn't always the best mode for maximizing glide ratio.

XFLR5 is an incredibly powerful program and with this simple introduction to it you should be able to explore many more options, like changing the airfoils, aspect ratios, or tail moments.

If you decide to do your own plane design, a program like XFLR5 is essential.

SHORT LINES

LSF's Newsletter

Issue # 12, March, 2016

The new Board

Ladies and gents,

As the new board we felt it appropriate to firstly introduce ourselves, share with you our mission and how we plan to achieve it. We would also like to share with you what we plan for this year at our US Soaring Nationals.

President: Larry Jolly, ljolly@aol.com

Larry is often referred to as the Grandfather of soaring; if it's a RC glider Larry has either flown it or designed it. Larry has been flying RC sailplanes for nearly 50 years and has represented many US soaring Teams along his journey.

Larry loves to be involved and we are thrilled to have Larry steering the ship for the LSF, his wisdom and experience will ensure the continued growth of this wonderful Special Interest Group, the LSF.

Vice President: Peter Goldsmith, Goldies28@hotmail.com

Pete is probably the most prolific RC enthusiast in the industry. He is instrumental in the promotion Horizon Hobby's products, often referred to as the Face of Horizon. Like Larry, Pete has been soaring all his life and is well versed in all forms of RC. Pete also has represented his country five times as a F3A pilot as well as flown in the famous TOC (Tournament of Champions). Although Pete flies all RC 'craft, his core passion is soaring. Pete's core skill set is marketing and he is looking forwards to being the marketing engine room for the LSF.

Secretary: Skye Malcolm, skyemalcolm@gmail.com
Skye is one of those people that is a quiet achiever. He, like all of our board, has been a sailplane enthusiast for many years and currently is the president of a large soaring club in Ohio.

Skye loves all forms of soaring, he has competed in all of the traditional classes and also loves slope soaring.

Skye is a detail guy, he is wonderfully organized and is the glue in ensuring tasks are kept on track. Skye manages the enormous list of LSF tasks so if you're planning in getting back to your level achievements Skye will be your contact.

Treasurer: Jim McCarthy, jmccarthy@edelston.com
Jim or Jimbo, as his friends call him, is the voice of reason. Jim has an incredible ability to be efficient, has a strong bias for action, yet do it in a way that doesn't ruffle feathers.

Jim has been a soaring pilot all his life and really enjoys the Man on Man environment of F3J. Jim is not limited to just sailplanes, Jim is an active RC Heli pilot as well. Jim's gift to the LSF is he has a bias for action; if you need something done, Jim's your guy.

Soaring Nationals

As new board members it's important for us to get a good understanding of where we have been, where we are, and where we need to go for the future. We have been busy surveying our membership through candid conversations, some of you may now understand why we were asking questions. Like with all surveys they are pretty much useless unless you act on the data. Based on the feedback we received there were several things that were common amongst our membership, some were good, some not so good. So our intent is to reach out to all Nats participants, and potential participants, and share what we will be doing this year.

Rules: Not to enter a long drawn out debate, we would like to consolidate the rules. The core event rules should be the same, as this allows for people flying in different segments to all have some kind of familiarity as to what is expected of them. We will be sending out additional specific information on some of the changes. However, the top points are as follows:

Safety line: After our survey, the safety line, although implemented with good intentions, has not really achieved its goal. Pilots standing too far away from their models were having trouble judging their approach, plus depending on which event you flew in it wasn't always there creating confusion and frustration.. It was also difficult to police consistently as there isn't enough resources to manage launches, winch repairs and policing in our out line calls. The solution was to remove the safety line in the landing area and implement a zero flight if the pilot hits him or herself or anybody in that matter during their flight. It's a self-policing change and brings consistency to our NATS. As competitors we are pretty sure this will ensure people will pay attention to approach speed etc. This change also brings us more inline with what other states and regions are doing. We will of course have a safety area (the space between the winches and landing lanes) where obviously you can't land.

On the subject of safety, the most dangerous part of a soaring flight is not so much the landing but the launch. This year we have added an additional person to help manage the flight line especially to help with launches, clearing winch lines and so on. Paying more attention to the launch will ensure a safer contest for all.

Landing zone: over the years we have seen a wide variety of landing areas, some as far as the eye can see, some, depending on your winch assignment are very restrictive. What we plane to do this year is follow in the F3J foot steps and introduce a 75m distance from the pilot's landing tape. It's the most fair and effective way to do this and, most importantly it will be the same for all classes. We will have a device on site for measuring those long landouts.

Introduce new pilots to soaring: As we are all members of the LSF it's imperative we are all looking out for new pilots. As the LSF board we see this as our most important task. Some of the things we want to do this year are aimed at the new comer. Nothing is more rewarding than to see your new friend or student have a good experience in a hobby or sport you have introduced him to. This year we have a exciting new idea.

It's called the "Buddy" program. If any first time pilot enters the NATS, we will assign him or her a buddy, an experienced soaring veteran to help them learn the ropes, mentor them to give them every chance to have a successful enjoyable time at the NATS. Most important, this will help new pilots connect at a deeper level to our segment. If you all remember your first competition you understand the anxiety. We feel this will have a huge benefits so please rustle those trees for new pilots.

Along the same lines we also want to try and implement having you be able to sign up with a partner so you can have a timer available for the entire contest. This was another hot topic with our survey.

Getting your entries in: Although the AMA registration states four weeks out, we have decided to allow registrations to be in by 7/15/2016. We do encourage you to get your entries in early, however we understand that life is a lot more spontaneous these days so we want you have a little more time to get those entries in. And, for those emergency entries we will have in the matrix some open place holders. Of course you will have to still register with the AMA, however that can be done on site. This change brings us more inline with other segments where later entries are accommodated.

Social activities: Many of the people we surveyed said we use to have a lot of fun things going on at the NATS, like there was something going on every night. If we are truly honest with ourselves, the competition comes second to the social element of most of the events we attend. Not to waste good input, we are planning to have something going on most nights. We are still in the planning stages and will get further details out in the coming months, however here is what we have so far. We want to do a Whipit event, BBQ, hand launch event, seminars, and aero-towing training.

Bring the family: Yes the number one disappointment we have heard is the importance of including the family at the NATS, it's a week long event so having the family involved makes it more fun for everybody. We need the kids to help out with the winches, wives/girlfriends can be timers and so on, get your family involved, they will love it.

In summary, we understand that your input is critical to the success of the LSF. In a short time we have discovered many things, things that can easily fixed and improved on. We want feedback, please send it to us, we can't promise immediate action on everything. However, if we see some patterns forming it will help us make better decisions. Our Job is to promote soaring, we are four people that speak for the many, and we want to be your voice.

Stayed tuned for more exciting news. Until then, keep soaring!

Kind regards, LSF Board

Tom's Tips

Bench coverings

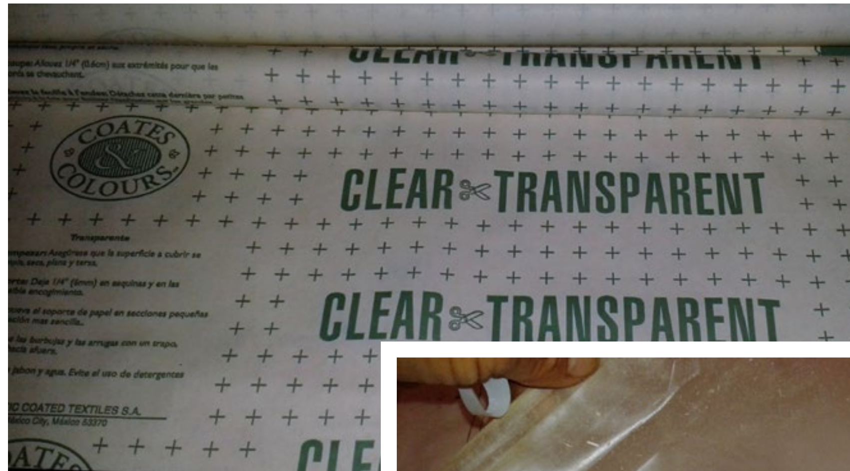
Tom Broeski, T&G Innovations LLC, tom@adesigner.com

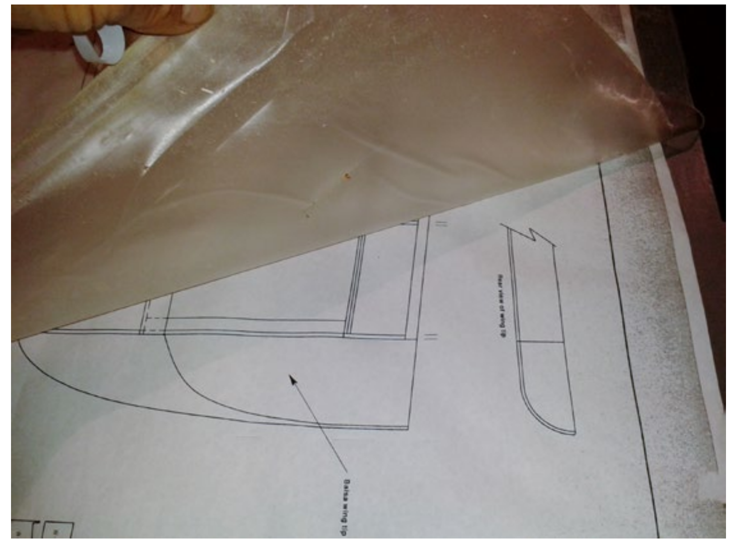
This is a “Wish I had done it when the bench was new” post.

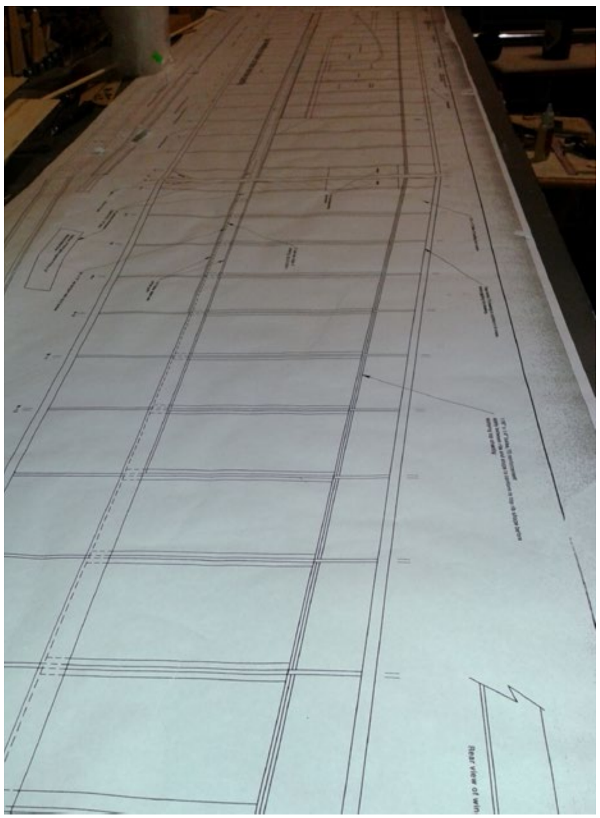
(1) Covering the bench top with Carpet Shield will make working so much easier.
It’s cheap and has lots of advantages and when totally worn out, just peel it off and replace it.

(2) Painted the old board and covered it. Looks great.

(3) Glue doesn’t stick.... Great for CAing sheeting together. Everything wipes off with ease. Dried yellow glue or epoxy just flicks off.







(4) Carpet Shield is good for permanent covering of plans. You can also use Duck Peel and Stick.

(5) For removable plan covering I use Coates Colours. There are also other clear shelf coverings with non-permanent adhesives.

(6) It peels right off the plans.

(7) CA does stick a bit, so sometimes I put it down first and then some Carpet Shield.

(8) Another great thing with Carpet Shield is that you can cut your covering right on it and it is thick enough that it doesn't shred apart and the bench itself doesn't get cut up. (If you don't press too hard that is.)

If you cross-cut too much, it may take a bit more time to remove and replace the covering, since there might be some small cutouts to peel off.

(9) I also use adhesive backed sandpaper on it to make a long sanding bar. Rolls right up when done and can be used over and over.

iDeA

Here is a new tool I made to hold a patch inside a fuselage or similar repairs. Made from a bicycle tire tube.

Stéphane Monfette
stephane.monfette@sympatico.ca

via the MATSCLUB Yahoo! Group
MATSCLUB@yahoogroups.com

A Micro Aerobatic glider to bring and fly everywhere!

Fred Marie, GliderIreland.net

Sometimes, you just design a glider, more for the laugh than anything else, and then forget about it... This is the case for the Micro Quark presented here. I designed it at the same time as the Quark 2M, just because... Well, why not!

I gave a few kits to friends if they wanted to play with it, and I have to say, I did not think much about it, and concentrated my attention to the Quark 2M and its success that followed.

I received a phone call last week, from Ronan, a guy that lives in Normandy, and during our conversation he asked me if I had a kit left for the Micro Quark for another friend... I was surprised he still had his glider, only to hear that his Quark was not leaving his car! He was flying it everywhere he goes, regardless of the wind, and this was a really fun glider!

OK, hold on a minute... Don't you just say that because you want a kit? Hell no! We want more of them! Right, time to go through the forum again, and look for the Micro Quark threads... And the flight reports were indeed really looking good at the time! How I missed that, I don't know, but today, the Micro Quark is back!

I made a few changes on the plan, so the model should be even lighter. Minimum amount of wood is needed, and I think you can get it done in less than a week from start to finish, or on the coffee table while watching TopGear with Jeremy Clarks.. Oh...

Specifications

WingSpan: 1.2m
Length: 0.88m
Profiles: SB96V - SB96VS
AUW: between 419 and 465grs for the prototypes - Yours will be lighter!
Servos: 4 minis
All wood construction

Materials

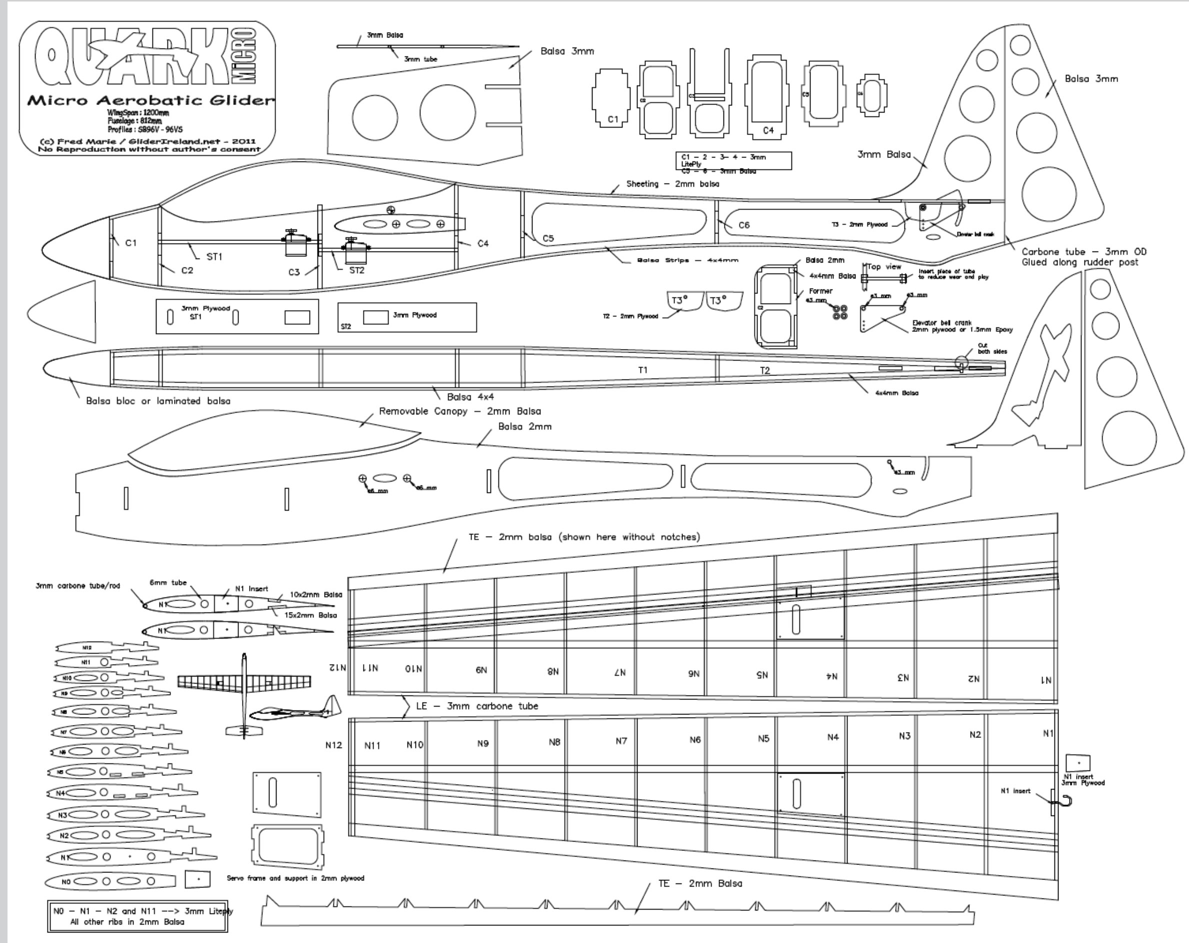
3mm Balsa: 1 sheet
2mm Balsa: 4 sheets
4x4mm balsa strips: about 4m
3mm LitePly: a piece of around 300x150mm
2mm plywood: a piece of around 150x90mm
3mm Carbon tubes: 2x600mm (LE) + 2x90mm (elevator) and 1x190mm (rudder)
6mm Carbon tube: 2x640mm (spars)
4mm tube or rods: 2x140mm (wing joiners)
Balsa block: around 60x60mm in size (nose - can also be made of stacked balsa sheets)

Centre of Gravity:

47mm from LE at root

Control throws:

No fear! Maximum everywhere!
You can add expo and dual rate for the first flights. No expo on the elevator!
Snap-flap would be a nice option, so is a bit of camber for those windless days.

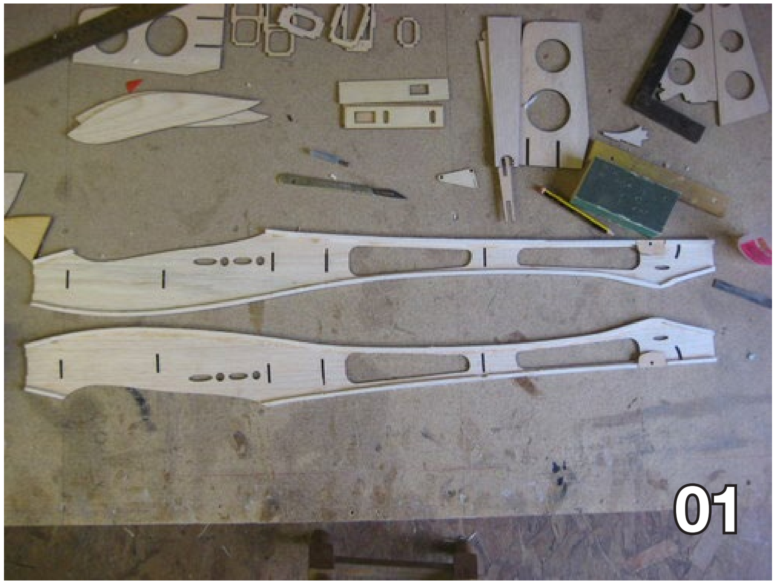


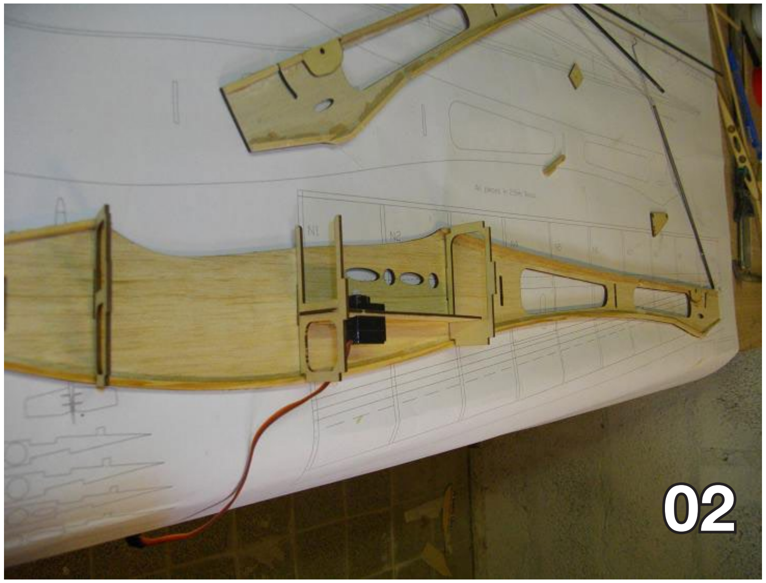
PLANS AVAILABLE

Full Size PDF plan (1000x800mm):
<http://gliderireland.net/images/Divers/Plans/QUARK%20MICRO%20-%20PLAN.pdf>

Full Size Plan in 15 A4 sheets to be assembled:
<http://gliderireland.net/images/Divers/Plans/QUARK%20MICRO%20-%20PLAN-A4.pdf>

SHORT KIT AVAILABLE (~50€)
<http://www.islandmodels.ie/index.php/sports-gliders/micro-quark-detail>

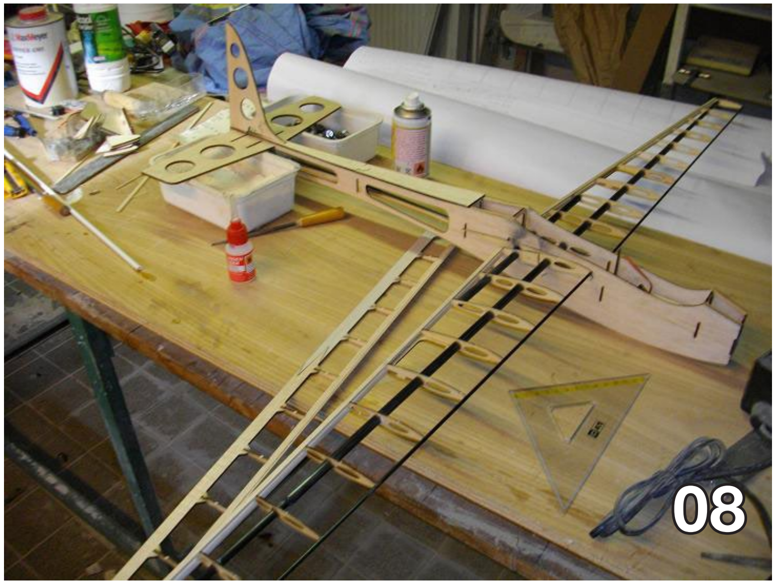




Photos 1, 2, 3: Basic fuselage construction

Photo 4: Vertical fin and rudder

Photos 4, 5, 6: Wing construction



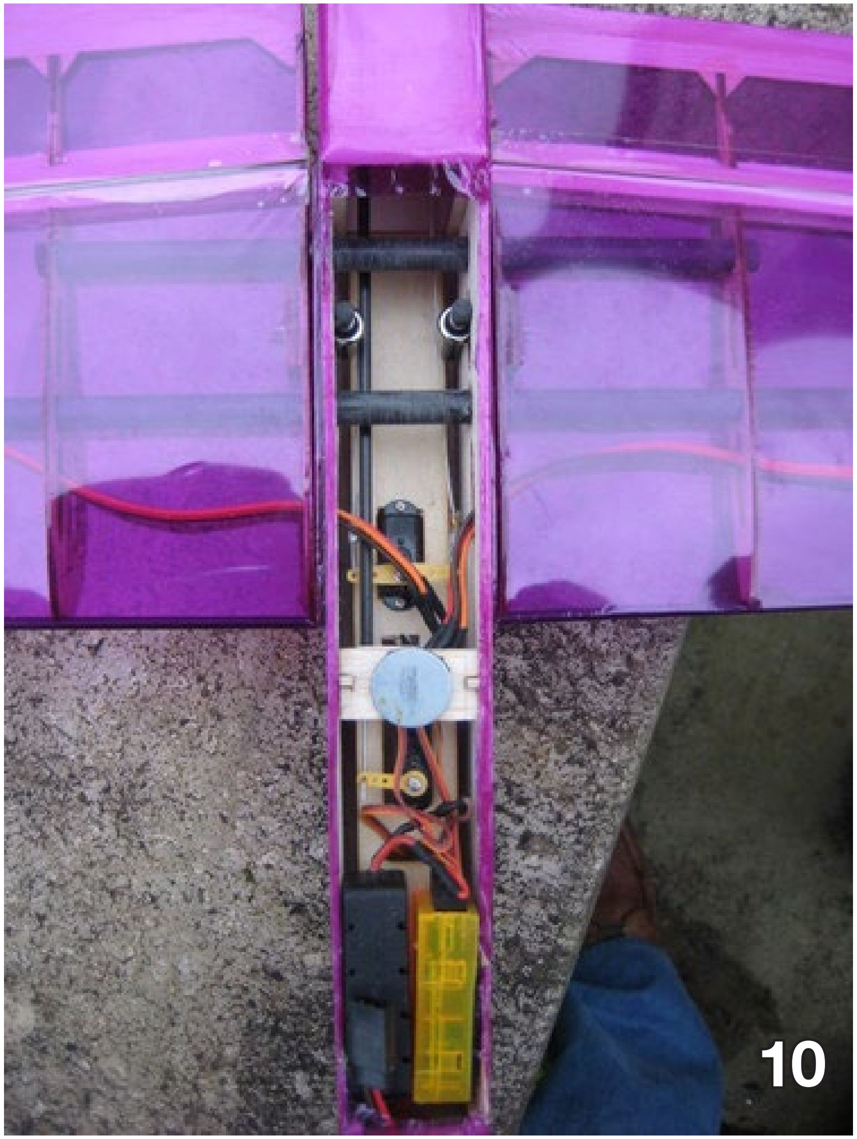


Photo 8: Component parts assembled

Photo 9: Servos mounted in fuselage

Photo 10: Internal view of the fuselage with wings attached

Photo 11: (L) Aileron version, (R) pivot wing version

Photo 12: Completed aileron version ready for flight

The build is relatively simple, just one or two things to be careful with, like the bell crank installation and the cutting of the ailerons, but that's what beer is for! Have a drink while studying carefully the plan for your next move, and everything should be fine!

Photos are self explanatory for the build, so I will not detail it here, but the forum is open if you have any questions for the build or to show us your build!

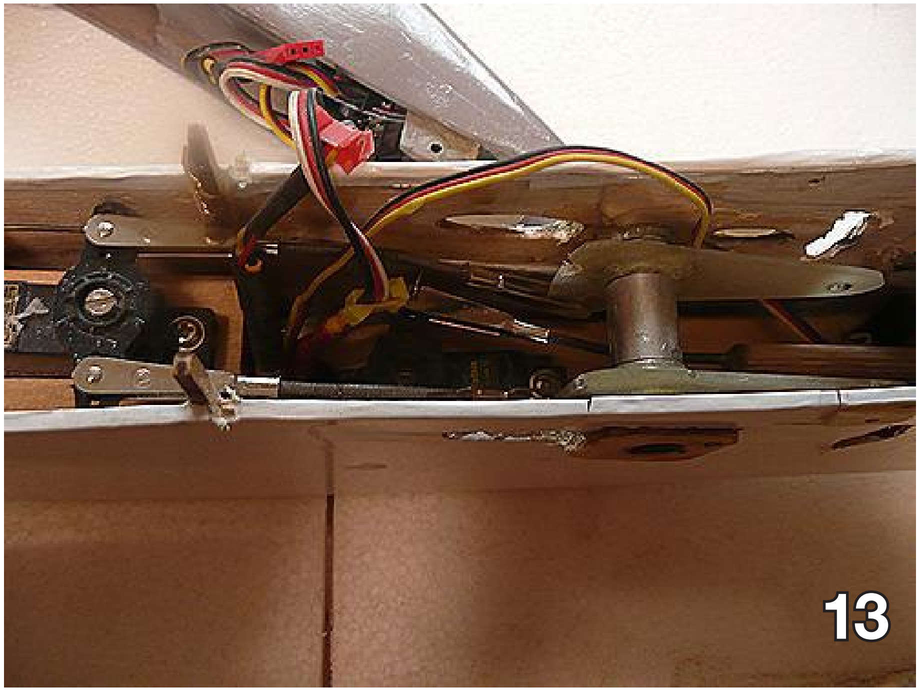
Plans:

- Full size PDF plan (1000x800mm): <http://gliderireland.net/images/Divers/Plans/QUARK%20MICRO%20-%20PLAN.pdf>
- Plan in A4 sheets to be assembled: <http://gliderireland.net/images/Divers/Plans/QUARK%20MICRO%20-%20PLAN-A4.pdf>

All free! How cool is that!

Short Kit Available (~50€):

<http://www.islandmodels.ie/index.php/sports-gliders/micro-quark-detail>



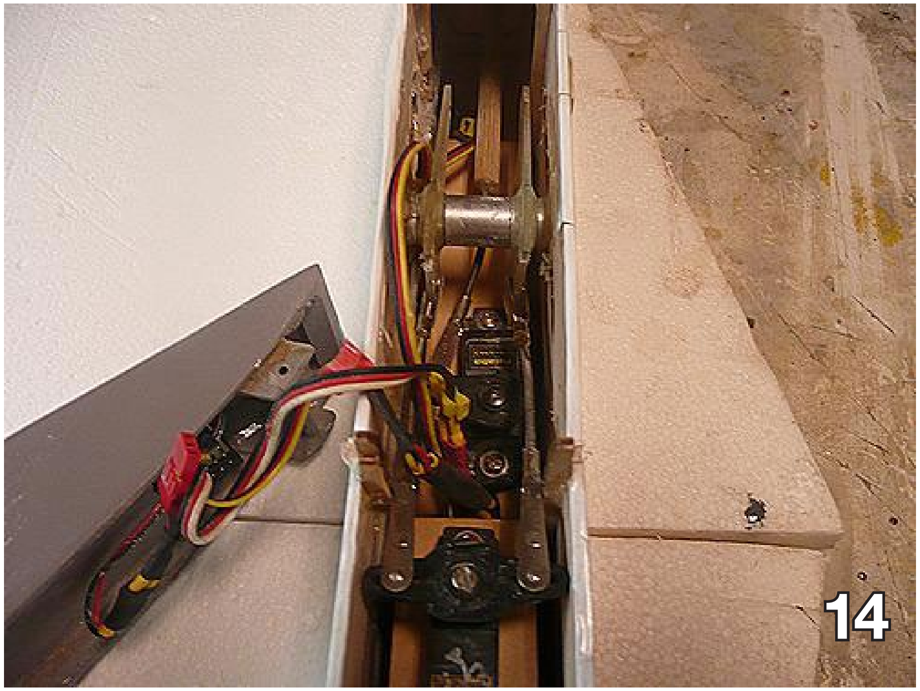


Photo 13, 14, 15: Interior details of the pivot wing version of the Micro Quark shown in Photo 12.

This is a rather intriguing and somewhat challenging option which requires a slightly different wing structure and the making of additional parts.

Those familiar with pivot wing mechanics should have little problem converting the plans.

Andrew Wallace's review of the Micro Quark (Thanks, Andrew!):

"When I received my kit of the Mini Quark I wasn't long on getting the bench cleared up and set about building the model. Within a couple of evenings work I had the model assembled and it went together really well - no issues at all only thing you had to watch out for was the bell crank for the elevator.

"I ordered the servos from eBay and due to the size of the wing ribs I bought four Turnigy micro servos. I used Balsaloc on the carbon leading edge and the model was covered in Solarflim. As I use 7.4v LiPo plus a regulator for my receiver

Photo 16 and 17: Micro Quarks ready to fly

Photo 18: First flight in Northern Ireland by Andrew Wallace

Photo 19: Ronan, Ralph, and Benben with the Micro Quark at Normandy

Photo 20: First flight of the Micro Quark at Normandy there wasn't much room in the fuselage for the battery, regulator and the receiver (I used an Orange 6 Channel) so I placed the battery in the canopy held in place with a bit of sponge and it worked a treat. The all up weight was 490g and the CG was on the main spar of the wing.

"I've had a good few flights with the Micro Quark; just over six hours flying time now and I've flown it in some very different conditions from light winds to very strong winds and on every occasion the little model performed.

"I had to upgrade the elevator servo to a Hi-Tech HS-81 as the micro servo wasn't strong enough for the all moving elevator and I changed the wing servos to Ripmax SD-100's.

"The model is fully aerobatic and can loop and roll as good as a powered plane and is capable of most manoeuvres.

"The size of the Quark is real handy and it fits in the car with the wings on so it's just plug in your battery and you're away. Thanks, Fred, for the opportunity to build and fly this great wee model."

With Micro Quark full size plans so readily available, relatively inexpensive construction materials, and construction taking so little time, we're hoping at least a few *RCSD* readers will build Micro Quarks for the upcoming flying season.

Photo 21: Ronan's Micro Quark

Entwicklung und Erprobung von Leichtflugzeugen

<http://www.eel.de>, kontakt@eel.de

ULF-1

The ULF-1 single seat foot-launched sailplane was designed by Dieter Reich and constructed by Heiner Neumann of Germany. Designed for ridge soaring and marginal thermal currents (Microlift), it has full three-axis aerodynamic control. Its first flight was in November 1977; its first public appearance was in August 1978 at the 3rd International Hang Glider Meeting at the Wasserkuppe, the historic German soaring site.

Since that appearance different pilots on a number of ULFs have accumulated many hours of flight time. The prototype alone has more than 150 hours total flight time in 200 flights, most of them starting from foot-launch.

More than 40 ULFs are believed to have been completed and flown. Fifteen ULF-1s are in operation in Germany. The longest flight lasted six hours; the maximum distance achieved 140 km. Both of these flights started with a foot-launch.

In July 1980, the ULF-1 design received an airworthiness certificate issued by the German authorities, after all required calculations and tests had been provided by the designer. In 1983 the Australian authorities gave approval for the ULF-1 to be built and flown in Australia. ULF-1 is, as far as we know, one of the best-performing foot-launched aircraft to date.

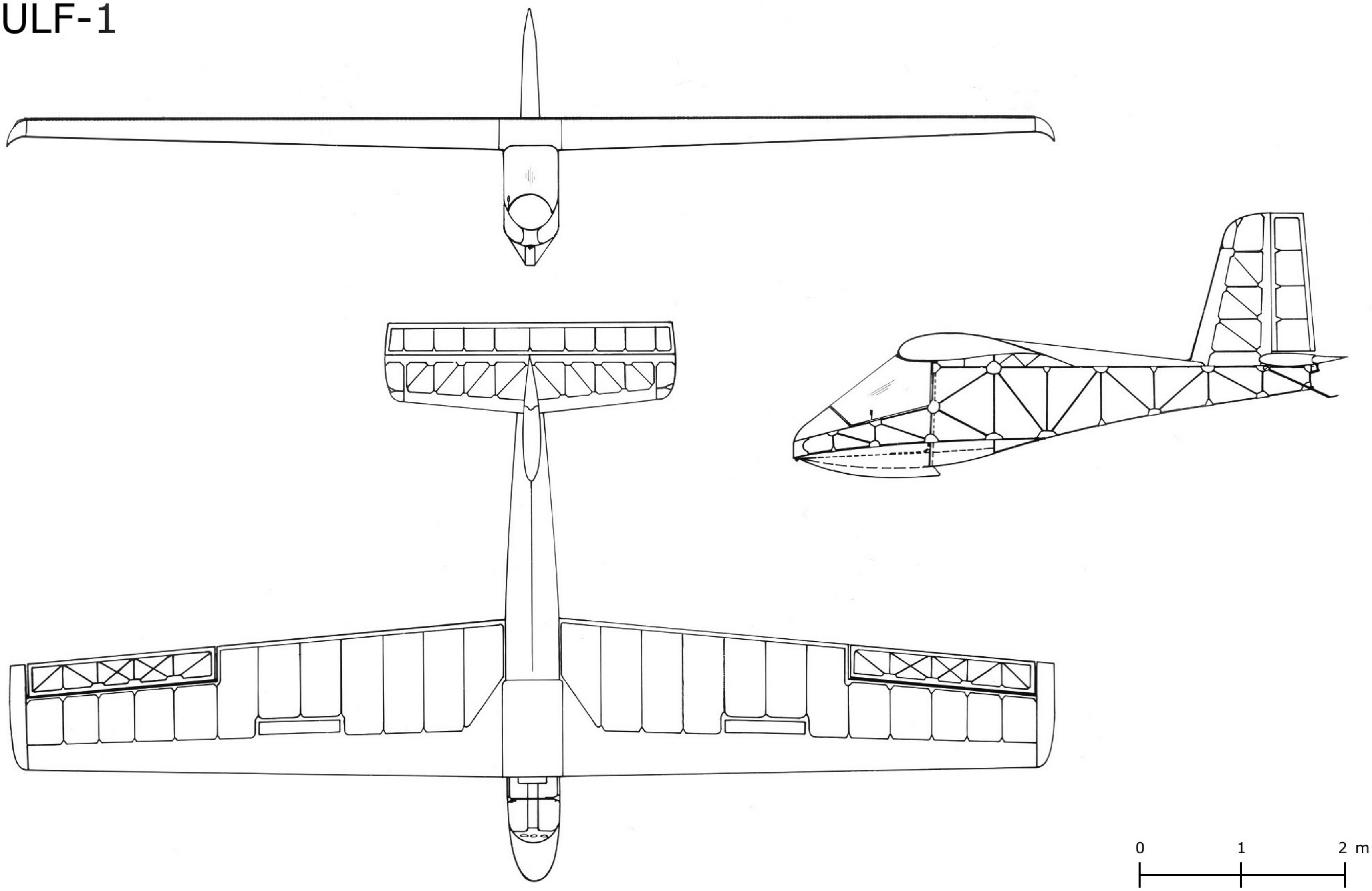
Operation

The aircraft can be foot-launched from slopes of more than 15 degrees even at small wind speeds. As the pilot starts the take-off ground run, the elevator stick should be in slight nose-down position to lift the horizontal tail. The moment the pilot feels a pronounced seat pressure; the control stick is pulled back until

the aircraft lifts off. After take-off the pilot retracts his legs and puts them on rudder pedals. A sliding slat-type construction behind the pilot's back can be released in flight to provide a seat.

Because of a low sink speed (0.8 m/s at max. take-off weight) and its good manoeuvrability, ULF-1 is sensitive to marginal thermal conditions. The best L/D of 16:1 is at around 55 km/h (about 34 mph). To reduce the aerodynamic drag of the fuselage, hinged doors have been fixed to the front

ULF-1



ULF 1 Technical Data

Type description	ULF-1, foot-launched sailplane		
Wing	Cantilever structure. Shoulder mounted, single wooden spar, plywood nose section, and wooden ribs, fabric covered. Wing section Wortmann FX 63-137, 18% thick at root, and 15% thick at tip. Spoiler on upper wing surface.		
Fuselage	Wooden frame of triangular cross section, fabric covered		
Tail	Cantilever structure, fabric covered		
Landing Gear	Nose skid, centre wheel, tail-skid (fibre glass tube)		
Instruments	Air speed indicator, rate of climb indicator, altimeter		
Dimensions	Wing span	10.40 m	34.12 ft
	Wing chord at root	1.53 m	5.02 ft
	Wing chord at tip	1.07 m	3.51 ft
	Wing aspect ratio	8.10	
	Length overall	5.55 m	18.21 ft
	Tail plane span	2.90 m	9.51 ft
Areas	Wing gross	13.4 m²	144.18 sq.ft
	Vertical tail	1.5 m²	16.14 sq.ft
	Horizontal tail	2.4 m²	25.82 sq.ft
Masses	Mass empty (without rescue system)	55 kg	121 lbs
	Max. take-off mass	155 kg	342 lbs
Ultimate Structural Load Factors	Positive	6 g	
	Negative	4 g	
Performance	Best glide ratio	16 at 55 km/h	34 mph
	Min. sink speed	0,8 m/s	157 fpm
	Min. speed	33 km/h	21 mph
	Max. speed (VNE)	80 km/h	50 mph

superstructure of the fuselage. They are kept open during take-off ground run and closed manually after lift-off. For "record-breaking" flights a closed Plexiglas windscreen is recommended.

It is estimated that both measures, the "landing gear" doors and the windshield, improve the L/D by ten to fifteen per cent, resulting in an L/D of 18. Since this glide-performance is also at a relatively high speed, the average cross-country cruising speed, including time for circling is at least fifty percent higher compared with conventional hang gliders.

Landing the ULF-1 is done on a nose skid located beneath the pilot's seat. The airplane can also be launched by bungee rope (down hill), winch, car and air tow.

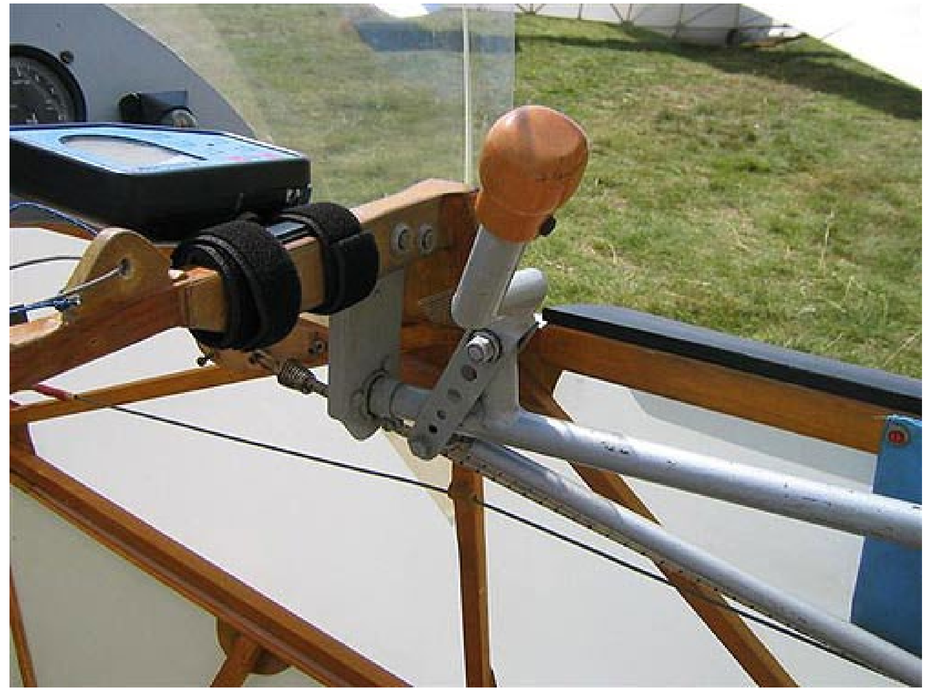
Handling Qualities

The three-axis aerodynamic control greatly reduces the pilot's workload compared to a conventional hang glider with its two-hand yoke bar, and frees one of the pilot's hands.

Dynamic pull-ups to about 20 degrees result in a smooth nose-down movement after the wing has stalled. In turns or in turbulent air, there is some wing drop in a stall. Recovery is properly and promptly achieved with opposite rudder. The loss of height is usually less than 10 meters (30 feet).


D-NZJH


D-NUDI



Construction

ULF-1 is specially suited for selfbuilders. The basic construction materials are spruce, birch plywood and balsa wood. The airframe is covered with doped fabric. For hinges, fasteners and fittings, aluminium, steel sheet and fibreglass/ resin are used. Steel tubes are employed only for the control stick, control parts in the cockpit area and rudder drive.

The ULF-1 prototype is equipped with a ballistic recovery system for both pilot and aircraft, located immediately behind the main bulkhead and activated by means of a mechanically released pull-out rocket. For road transport, the two-piece wing can be detached. In addition, the horizontal tail can be removed. The aircraft can be taken off a trailer and assembled in about ten minutes.

Full size plans for the man-carrying ULF-1 are available from Entwicklung und Erprobung von Leichtflugzeugen. See <http://www.eel.de> for ordering information.

Marske Aircraft

Pioneer III

Jim Marske is probably best known for his Pioneer series of tailless sailplanes, particularly the Pioneer IID. Designed for the amateur glider builder, the Pioneer II was of wood construction and designed to be built in a standard garage. Over the next 20 years, Jim shifted his focus to designing high performance, low drag airfoils to achieve lower sink rate and increase the speed range of the aircraft.

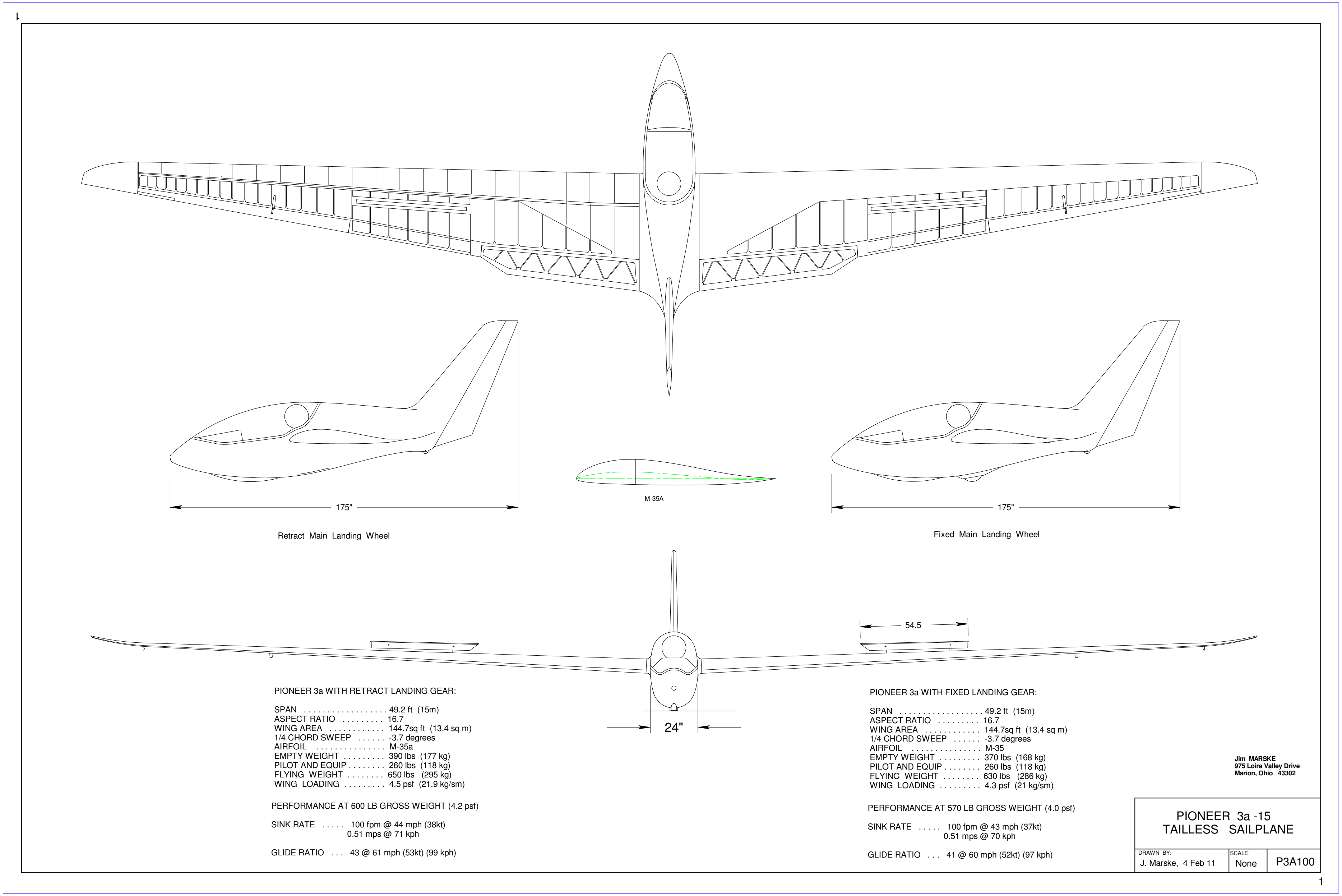
Jim has recently finished development of the Pioneer III, a tailless, all composite, lightweight aircraft - 100lbs lighter than the wood wing Pioneer II. The Pioneer III enjoys a 20% reduction in wing drag resulting in an excellent sailplane that can perform exceptionally well under weak lift conditions. On its first attempt to soar under marginal thermal conditions, the Pioneer III made a 5 hour flight. On its second flight, it flew a 60 mile round trip, being careful to stay within the limits of the FAA flight test area.

Performance of the Pioneer III is very close to the ASW-27 at speeds between 42 and 75 kts.


N41699
PIONEER 3

Above left: Interior details of the wing showing the aileron control system. Left: Open spoiler. Note the composite rib structure. Above: Elevator under construction.

Left above and left: Cockpit interior. The small wheel on the left side cockpit wall moves a weight fore and aft for high speed and low speed CG trim. Above top: Jim and the Pioneer III. Above: Flying field assembly.



Quarter scale drawings for the Pioneer III are available from the RCSD web site: <http://www.rcsoaringdigest.com/Supplements/P3_scale_drawings.zip>. This collection includes six large sheets showing fuselage (1) and wing (3) layouts, fuselage bulkheads (1), and wing ribs (1).

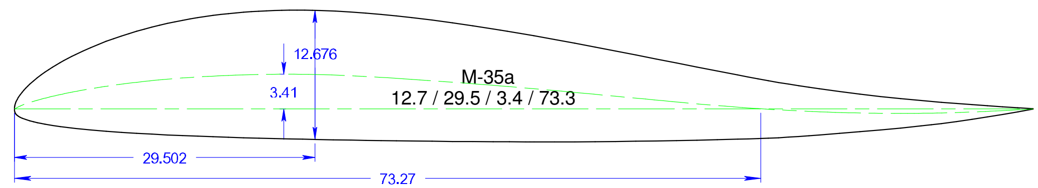

Marske Aircraft
Pioneer IV

The Marske Aircraft 15 meter Pioneer IV has made a few low hops so far off the winch before winter stopped operations. It shares essentially the same planform as the Pioneer III, with only a minor change to the trailing edge contour in the area around the outer end of the central elevator. Huge differences appear in the airfoil used and the construction materials.

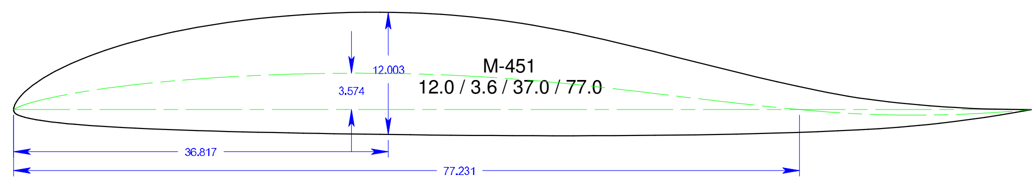
The Pioneer IV airfoil has a sharper leading edge, is slightly thinner, has a bit more camber, and a reflex point further aft than the section used on the Pioneer III. Additionally, the upper surface high point is moved aft, extending the area of laminar flow. With the new laminar airfoil Jim expects the L/D to reach 50 or better.

While the Pioneer III used composite wing ribs - corrugated fiberglass wing ribs with wood caps - the Pioneer IV wing is made using foam core technology. This method of wing construction exactly parallels what RC soaring enthusiasts have been doing for decades.

Matt Kollman made his wire cutting machine himself. You plug in the ordinates, flip the switch and sit back and watch it. The airfoils can be different at each end and a different chord length. Even chords of 2" come out perfect. The 60" chord required doubling the number of points to get a smooth cut.



PIONEER 3 Airfoil



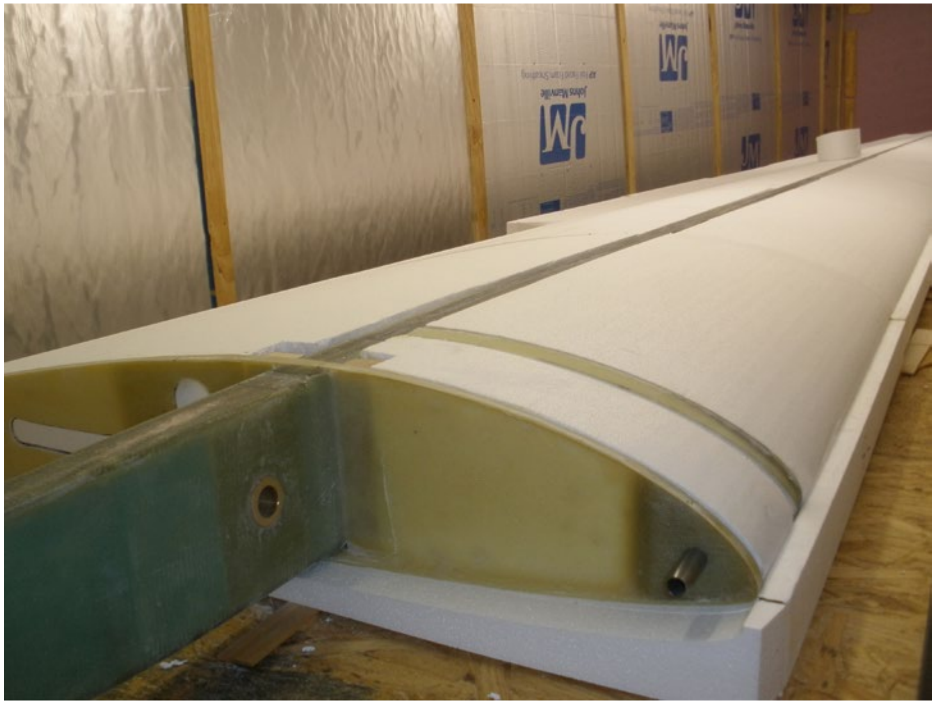
PIONEER 4 Airfoil

The foam segments were kept down to 42” maximum to prevent wire sag.

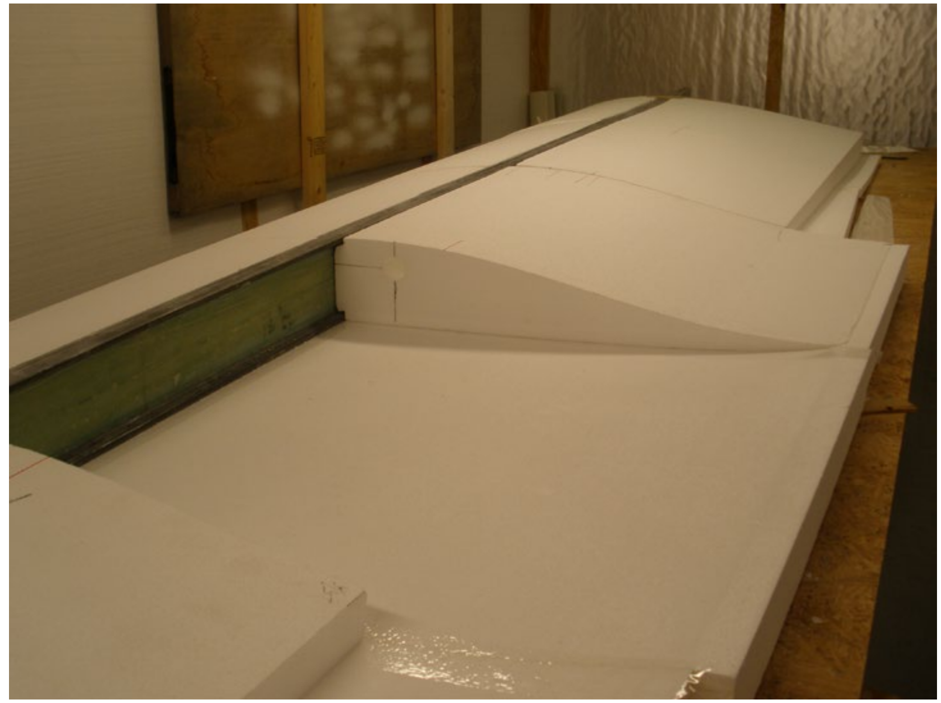
Matt has been doing infusion molding for all of the parts. He is planning to do the entire wing panel using the infusion process. The parts come out near perfect with no pin holes.

The foam block from which the core was cut was used to create a sandwich to compress the entire wing under vacuum. The wing came out just as you see it in the assembled glider photo. A bit of sanding at the leading edge was required to get rid of the flashing.

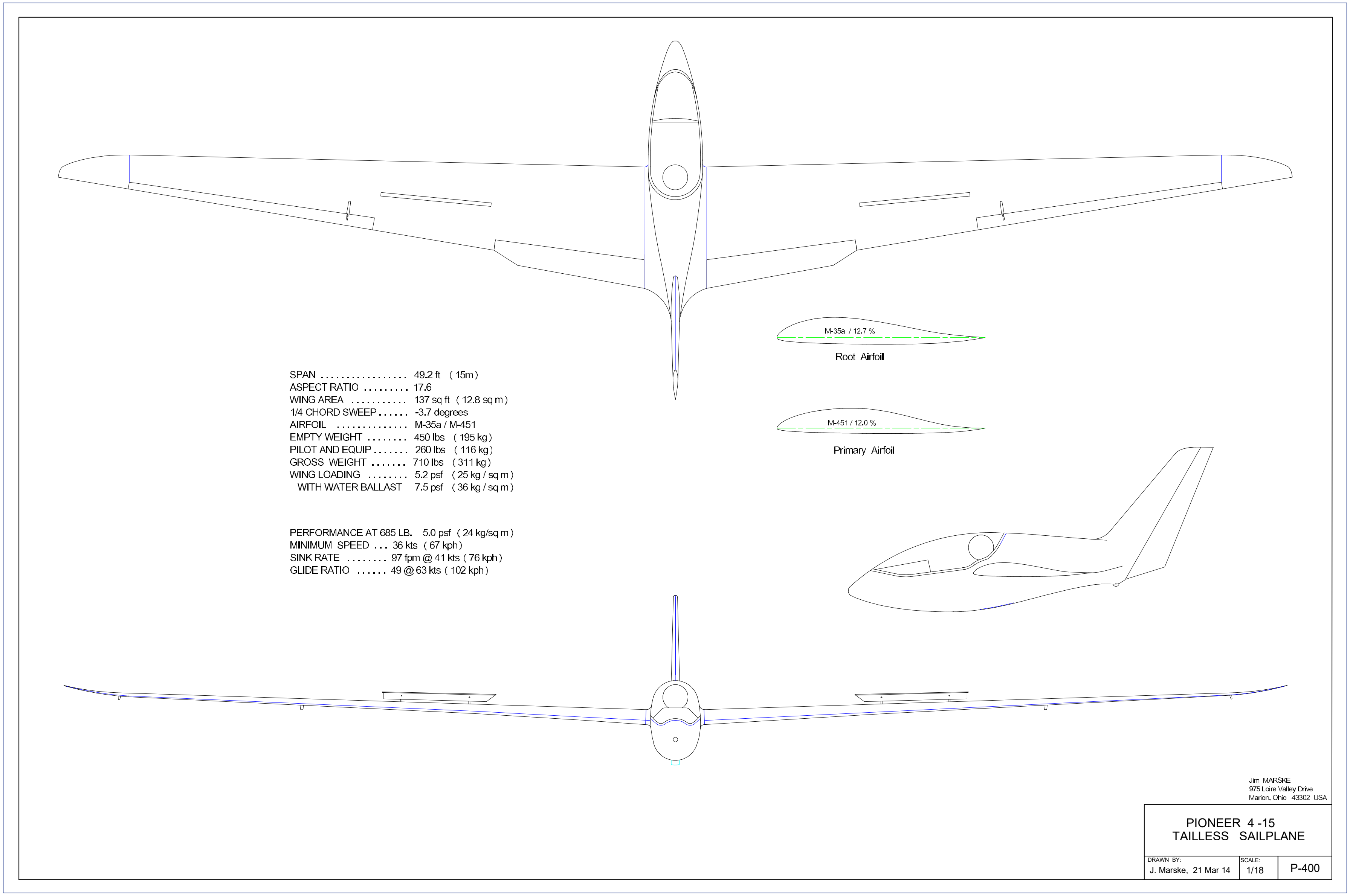
The Pioneer IV has an aspect ratio of 18. It features a retractable mainwheel. Water ballast vary between 5 an 8 psf.



Upper: Left wing core showing root face, alignment pin and spar assembly. Above: Wing core showing the airfoil shape.



Upper: Wing “guts.” Aileron cutout at rear, composite spar in place, elevator cutout at forefront. Above: Wing tip core.



Note: This 3-view scaled to match Pioneer III 3-view.

Going *Mobile*

Trevor Ignatosky, trevor2@optonline.net

If you use a small mobile device you'll find most RC soaring club websites are not mobile-friendly. Those websites are best viewed on the large, wide displays used by desktops and some laptops. Fast internet connections may help, too.

When a club website is difficult to navigate and view on a mobile device, has tiny buttons and text requiring pinching and zooming to be able to use or read, visitors to the website are going to feel the website doesn't accommodate whatever type of device they're using, get frustrated and leave. Those visitors could be potential new club members or even its own club members. Blame mobile technology, smartphones in particular, for creating this situation.

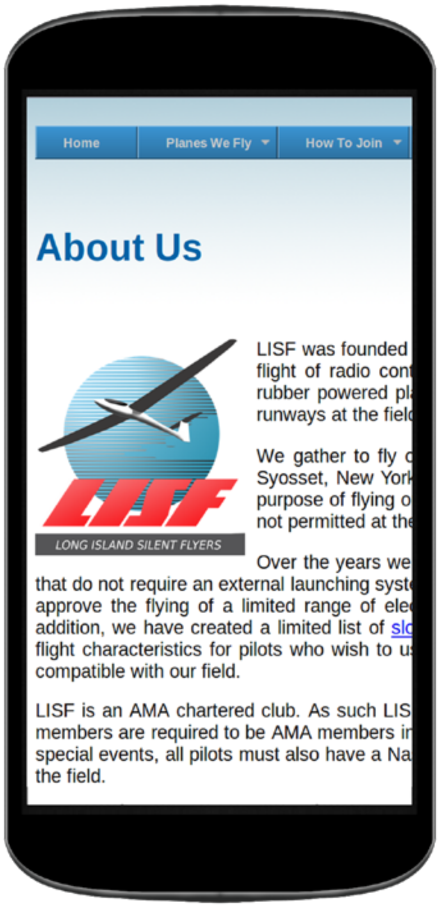
There's a three second rule. When people go to a webpage and the page doesn't load in three seconds, they get frustrated and leave. Do a little research online and you'll find that the three second rule is becoming the two second rule. You can see where this is going. As people get accustomed to fast they start to demand faster yet.

So far we've only touched on usage and speed. Added to these problems is that Google, the world's most used search engine, demotes websites that it deems non-mobile-friendly in its search results.

Taking a club's desktop website and making it mobile-friendly is by definition a solution to these problems. But it leaves clubs with three new problems in place of the original three: making a decision to go mobile-friendly, finding someone to convert their website from a desktop website to a mobile-friendly website and paying for the job.

If a club's webmaster is a volunteer and is willing to and capable of making this change then there's only one problem: getting the club to make the decision to go mobile. If not, the club may find that changing to a mobile-friendly website is beyond its resources or its funds are better spent elsewhere.

One type of difference between a webpage designed for desktops (left) versus a mobile-friendly webpage (right) on a smartphone.



Another way a website designed for a desktop can look bad on a smartphone. Most of the right side of the webpage is chopped off.

How easy or hard can going mobile be?

Creating a website can be done by mostly pointing-and-clicking. It has its limitations and there's still a learning curve, but it may be all you'll need. We'll go into this later.

In March 2013 I took over as our club's webmaster. Our website had been created using Microsoft FrontPage, which was ancient technology even then. Our website contained only a handful of webpages, so I decided to recreate it by rewriting its code from scratch; one line at a time. It was a learning exercise and, best of all for the club, it was free.

I used W3Schools's tutorials <http://www.w3schools.com/> to learn to write the code. It's free. It's easy. It's fun.

Don't believe me? Go to their webpage, open the first html example, copy the few lines of code in the example into a text editor (e.g. Notepad, not Word), save it to a file named test.html and finally, open the new file in your web browser. Ta-da! Your first webpage.

Now go into the code, modify the text to be displayed by the web browser, save it, reload the webpage and view the results. Do you feel empowered?

Using the examples in W3Schools's tutorials I was able to start off with simple webpages for our website and then add more webpages, more content and more features to them as I went along. What I ended up with was another desktop version of our website. Three years ago that was good enough.

Using <http://www.w3schools.com/html/html_responsive.asp> W3Schools lessons, you can create a mobile-friendly (responsive web design) webpage step-by-step. Using their Bootstrap tutorial <http://www.w3schools.com/bootstrap/> I hand coded our club's mobile-friendly pages in April 2015. It's going on a year old and it's still good enough.

Hand coding has another benefit. If you don't know how to implement a feature on your website, to paraphrase rule number eight of Dave Thornburg's Rules, "Piggybacking off another website also works!" So if you find a website that has a feature you like, check out how it was done using Firefox or another web browser that allows you to view a webpage's source code.

As much as webmasters may not like to admit it, other people's websites can be great teachers.

Try it out

Our club's website is a good example to experiment with. It has desktop and mobile-friendly webpages that can be switched between. It's also a website that club members can relate to if you want to argue for your club's website going mobile and need to demonstrate mobile-friendly versus desktop webpages on a smartphone.

The desktop version and mobile versions of our website are both complete on their own and they both serve up as much of the same content as possible. In general they look similar and, since I pretty much kept the old menu structure, have a similar feel, too. The files and images are shared between the two versions, so it's just the webpages that are different.

You can access them here:

> old (so last century) desktop version:
> http://www.lisf.org/home/home/home_desktop.html
>
> new (passably modern looking) mobile-friendly version:
> http://www.lisf.org/home/home/home.html

Note that you'll need a more modern web browser to properly view a mobile-friendly website.

What I do to view our website on a desktop monitor is to open my web browser's window (I use Firefox) as large as I'd like to view it and then zoom in and out with Ctrl- and Ctrl+ to find the best sized text that is easy to read. How you set up your browser's window comes down to your display's dimensions and your personal preferences.

To use a wide screen computer to get an idea of our mobile-friendly website's capabilities, open the mobile-friendly Home page in your web browser and resize it, so that it covers about three-quarters of the display screen.

Zoom in or out until the Home page fills the web browser's window comfortably and the text is easy to read.

The old familiar desktop home page on a wide screen display.
Courtesy of Dell Inc.

The mobile-friendly home page on a wide screen display.
Courtesy of Dell Inc.

Now try grabbing a side edge of the browser window and resizing the browser window to see its effect.

You'll be simulating viewing the page on a smaller mobile device as you make the window narrow. What you'll see is the images change in size and the number of columns displayed on the screen change to give you the best viewing experience.

Now try the same experiment using the Home page on our desktop website.

You'll find that making the screen narrow pushes part of the webpage off the edge of the window. It doesn't hold up very well in a comparison to the mobile-friendly version, does it?

(If you're using a tablet rotating the device to view the screen in landscape or portrait mode may show our desktop webpages look fine. Remember that trinity of problems that webpages designed for desktop computers suffer from? They don't go away just because a desktop webpage isn't visibly screwing up on a particular device.)

There is something else to be learned from this exercise. The mobile version isn't only good for mobile devices. It can make your viewing experience on everything sized between a small smartphone and a large desktop a lot better, too.

By now you're probably wondering why our club's website still has a desktop version in addition to a mobile version since it takes an extra effort to maintain both.

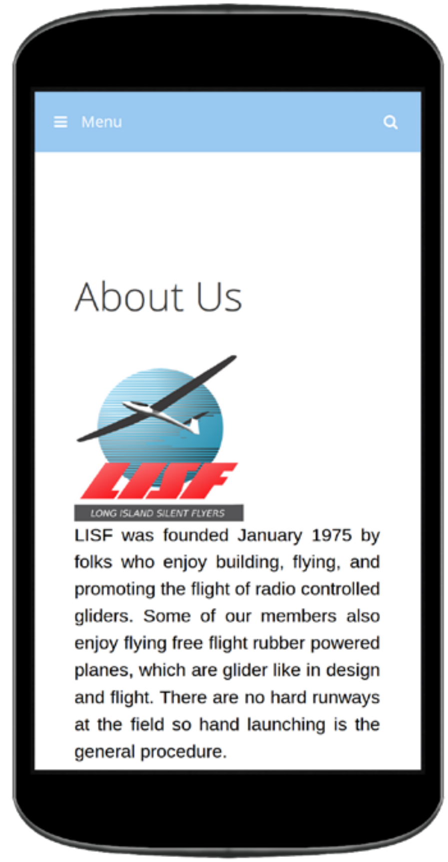
We continue to support our desktop version for visitors who have older web browsers that don't work well with mobile websites and who refuse to let go of them or simply can't upgrade because a modern version of their favorite web browser isn't supported on an old operating system.

By using the old, familiar desktop version they won't miss anything except for a better viewing experience and our club is less likely to lose them as visitors.

Content Management Systems

I added a mobile-compatible Home page with an About Us page on our website to serve as an example of what can be created using WordPress, a free web content management system (CMS), with the GeneratePress theme. If you feel like shopping around, there are plenty of other CMSs and themes to choose from.

WordPress mostly uses point and click to work its magic. This lowers the barriers of entry for folks to use it for creating functional, easily modified and good looking websites. In that same vein, there are plugins for adding various features, should they be desired.



This mobile-friendly webpage was created using Wordpress, a popular content management system that is currently powering twenty-five percent of the world's websites. All the content when viewed on a wide screen is still available on this screen size.

Wordpress uses themes to change the basic appearance and functionality of the webpages created with it.

Some of the available themes are mobile-friendly, also known as responsive web designs.

The GeneratePress theme was selected for this example because it creates webpages that are mobile-friendly and that can be setup to look similar to our mobile-friendly webpages which mostly have three columns when displayed full screen.

> WordPress created mobile-friendly webpages:
>
> http://www.lisf.org/home/wp_demo/about-us/

Some pieces of code from our mobile-friendly website were used to make the picture cycling work. It could also have been accomplished using a plugin.

Themes and plugins are how WordPress developers make money, but there are plenty of free versions around. By the way, plugins, in my opinion, should be kept to a minimum for security.

If you haven't already, I recommend that you go online and checkout our website. The example webpages shown here were chosen for their simplicity, which doesn't do the abilities of a mobile-friendly website justice.

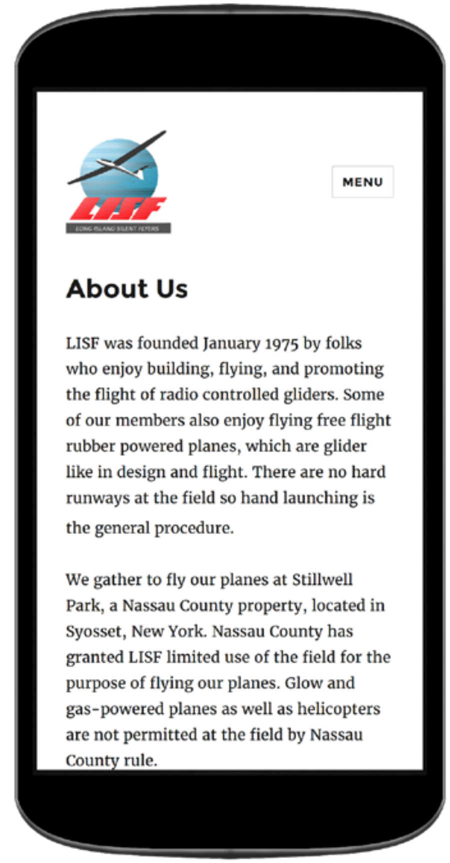
A Free WordPress Website

WordPress will host a simple website for you for free at <https://wordpress.com/>.

Combine free hosting with WordPress itself and plenty of themes, some of them responsive web designs, and you have a combination that's hard to beat.

One negative is a three gigabyte storage limit: still plenty for starting a club's website or creating a prototype website for demonstration. Also, the WordPress version used is somewhat stripped down. Hey, they have to give users incentive to step up and spend money.

Here's a sample <https://lisfblog.wordpress.com/about/> that is for our club's website. Creating a website like this is a good introduction to using WordPress.



A simple WordPress webpage created and hosted for free, zero, zip, ziltch, nada, nothing.

Selling the Idea of Going Mobile

By this point you might be sold on the idea of your club's website becoming mobile-friendly. So how do you sell it to your club?

Comparison of the desktop and mobile-friendly versions of the same website has worked to get acceptance for a website to go mobile during an organization's council meeting. All it took was an iPhone and rotating the phone to show a mobile-friendly website in landscape and portrait modes versus the desktop version of the same website in landscape and portrait modes. This was after barely getting anyone's attention with merely talking. Sometimes words don't get the message across with the same impact that a demonstration does.

If you need the two-by-four to convince folks, Google PageSpeed Insights provides tests with grades for websites at <https://developers.google.com/speed/pagespeed/insights/>. Per Google, "PageSpeed Insights analyzes the content of a web page, then generates suggestions to make that page faster." It also analyzes and grades user experience. When done, Google doesn't just leave you with a report, but shows how to fix the issues found.

Our club's mobile-friendly website doesn't pass all of these tests. That's because there's a limit to how much time I'm willing to invest tweaking webpages with diminishing returns. Not surprisingly, the PageSpeed Insights webpage doesn't pass its own tests one-hundred percent either. So how well does your website do? It only takes a minute to find out.

For Webmasters

Even if you haven't read through this article completely you probably have some knowledge about going mobile after Google splashed into the news last year with "mobilegeddon". With so many articles about mobilegeddon on the internet, here is one that is different. Instead of looking forward, it looks back on the results.

<http://blogs.wsj.com/digits/2015/07/15/googles-mobilegeddon-was-a-big-deal-after-all/>

I'll summarize here what I've done to set up an example WordPress mobile-friendly website alongside our club's website. It doesn't replace our website since it has a different web address. I'm going for the big picture with this example, so I encourage you to follow the links at the end of this article to documentation that gives more detail.

My goals, besides setting up an example WordPress website to help reader's get their feet on the ground, are to do the job myself and do it for free. When I'm done, I'm the one in control of it, not someone holding their hand out for money.

Our club's web host must be able to host a WordPress website. This means the web host has to provide some services in the background that WordPress needs to run. In addition WordPress needs a database.

A database must be created and setup that Wordpress will use to run the new website. Your web host should be able to give you guidance for setting up a WordPress database, if required.

Our web host provides MySQL Database. After logging into their website, clicking on their icon for MySQL Database takes me to a MySQL page containing a Manage Databases tab. This is where I get managed, as it imposes limitations on choices I make for database name, user name and password. Only when my choices are acceptable will it create a new database for me.

The MySQL page also gives a critical piece of information, the so-called server name, which I'll need later.

For your future reference: From that same page I can access and manage the new database via phpMyAdmin, a program which runs in my web browser. If I use phpMyAdmin to look at the new database at this point I'd find that the database has zero tables. After firing up the website, and WordPress has its way with it, it will have twelve tables.

Next I go to <https://wordpress.org/download/>, download the latest copy of Wordpress and extract its files and directories to my computer.

I create a copy of the wp-config-sample.php file in the wordpress directory, that was just created, and name it wp-config.php. This will be the configuration file that the new WordPress website uses.

Edit the wp-config.php configuration file using a text editor like Notepad, not a word processor like Word. Replace database_name_here, user_name_here and password_here with the appropriate values from when the database was setup. Replace localhost with the server name that was given when setting up the database and then save the file.

Copy the Wordpress directories and files to wherever the original website is by using file transfer protocol (FTP). Generally, and specifically in our club's case, it's in a directory called public_html. I use the Filezilla FTP program for this. Your web host should be able to give you guidance for setting up FileZilla to work with their system, if required.

Use FTP to rename the Wordpress directory on the web host to something appropriate. I'll name mine "wp_example".

I take my club's web address and tack on /wp_example/ to it <http://www.lisf.org/wp_example/> and then open the address with my web browser. WordPress Install asks for my language and then goes on to ask for more. It knows my user name, and suggests a password, but needs a site title and my email address. I replace the suggested password with the password I used for the database and use "Example" for the site title. WordPress will start sending email notifications to me with the email address I give, so I need to give some consideration to where I want them to go.

Click on "Install WordPress" and then "Login". WordPress will then open a Dashboard webpage. This is where I'll start to administer the new website. If I want to see what it looks like I click on the Home Icon in the upper left corner. That opens the new website as others will see it. The new website is set up for blogging to start with, but I can start making changes to mold the new website into the sort of website I want.

In Conclusion

This magazine has a readership of about three thousand. Assuming an average club size of thirty members, this article could be read by the members of one hundred RC sailplane clubs worldwide. Going by a quick survey of RC sailplane club websites, most still aren't mobile-friendly. That translates to a lot of visitors to RC sailplane club websites in need of a better viewing experience and is the primary reason you have this article.

I hope this article gives some of you the incentive to see that your club's website is or becomes mobile-friendly. After all, tweaking a website that's made for desktops, no matter how pretty it ends up looking, doesn't make it mobile-friendly. And if it isn't mobile-friendly, it isn't going to do as well as it could in Google's version of a popularity contest and at garnering visitors.

References:

Download WordPress:
Besides being the source for downloading WordPress, this web page has a link to a guide for installation, one for upgrading your installation and another for support forums. All are strongly recommended.
<https://wordpress.org/download/>

The GeneratePress theme:
Since an example given here uses the GeneratePress theme, readers may want to try it out. GeneratePress has given good and timely responses when their input was needed and this theme has worked well over time for a website I've setup. That said, it's only fair to point out that there are other mobile-friendly themes that may be better suited to your club's particular needs.
<https://wordpress.org/themes/generatepress/>

The WordPress theme directory:
A WordPress website isn't married to any particular theme. If you don't like one try another. I would check their reviews first to avoid headaches.
<https://wordpress.org/themes/>

The WordPress Plugin directory:
There are only 43,123 plugins for WordPress at the time of this writing. Some are good and some not so good. Like with WordPress themes, check them out before using them to find which ones are truly effective for what they claim to do.
<https://wordpress.org/plugins/>

Setup a free WordPress website:
WordPress will host a simple website for you for free.
<https://wordpress.com/>

Here is a summary of the example websites used in this article, so you can load them up in your web browser and switch between them doing comparisons:

desktop website (hand coded):
<http://www.lisf.org/home/home/home_desktop.html>

mobile-friendly website (hand coded):
<http://www.lisf.org/home/home/home.html>

WordPress created mobile-friendly webpages. Only the Home and About Us pages were created using WordPress:
<http://www.lisf.org/home/wp_demo/>

Free WordPress created mobile-friendly webpages. Only the Home and About Us pages were created using WordPress.:
<https://lisfblog.wordpress.com/home/>

http://f3k.su/rainbow-2016/

FAI Event ID: 11109
<http://www.fai.org/ciam-events/ciam-events-calendar-and-results?id=31550&%3BEventCalendarId=11109#fragment-1>

ETUC number 10514

Competition Regulations (English):
<http://f3k.su/ocontent/uploads/Regulations-EN-of-the-World-Cup-stage-under-the-FAI-Cup-and-Rainbow-F3K.pdf>

V&P Scientific, Inc.

Viscosity Table

http://www.vp-scientific.com/Viscosity_Tables.htm

Most *RCSD* readers have worked with epoxy. Whether laminating multiple layers of materials, vacuum bagging structures, or making a spot repair, the choice of the epoxy used is nearly always directed by the desired "thickness" of the epoxy after thorough mixing and before application.

If we want the epoxy to flow readily through fiberglass cloth, we want a thinner mix. On the other hand, if the epoxy must stick to a vertical surface, it will obviously need to be very thick.

Viscosity is the measurement of a fluid's internal resistance to flow. This is typically designated in units of centipoise or poise but can be expressed in other acceptable measurements as well.

Epoxy manufacturers are quite helpful when it comes to determining the viscosity of the various brands and types available, but the data is usually provided in cps. Here's a viscosity table which relates cps to common fluids. It can be reproduced and tacked on the building room wall so it's always convenient.

Approximate Viscosities of Common Materials (At Room Temperature-70°F) *	
Material	**Viscosity in Centipoise**
Water	1 cps
Milk	3 cps
SAE 10 Motor Oil	85-140 cps
SAE 20 Motor Oil	140-420 cps
SAE 30 Motor Oil	420-650 cps
SAE 40 Motor Oil	650-900 cps
Castrol Oil	1,000 cps
Karo Syrup	5,000 cps
Honey	10,000 cps
Chocolate	25,000 cps
Ketchup	50,000 cps
Mustard	70,000 cps
Sour Cream	100,000 cps
Peanut Butter	250,000 cps

Some conversion factors are as follows:

100 Centipoise = 1 Poise
1 Centipoise = 1 mPa s (Millipascal Second)
1 Poise = 0.1 Pa s (Pascal Second)
Centipoise = Centistoke x Specific Gravity

AERION AS2
CORPORATION

The perfect scale "lead sled" sloper for those with PNF (RCSD-2011-09)

The AS2 is different than any airplane that has come before, principally in terms of aerodynamics and sheer performance. Its outline is the new shape of practical and efficient supersonic flight. A supersonic natural laminar flow wing and other drag-reducing features set it apart.

Supersonic natural laminar flow (SNLF) is a truly disruptive technology. Just as speeds doubled in the leap from piston transports to the jet age of the 1960s, so they will accelerate once again with the advent of supersonic speed.

In traditional subsonic airplanes, wingspan and fuselage length are roughly equal. The AS2 is characterized by relatively short, thin wings and a long fuselage, much like some supersonic fighters, and for similar reasons. The Aerion wing vastly reduces friction drag and the Aerion fuselage minimizes wave drag.

For all its outwardly different looks, it is in other respects conventional, using the very best of modern structural materials and assembly technologies, as well as advanced systems for propulsion, flight control, environmental control, and more.

WING

Supersonic flight has been possible since 1947, when Chuck Yeager broke the sound barrier in the Bell X1. The great challenge, from a commercial standpoint, has been to make supersonic flight

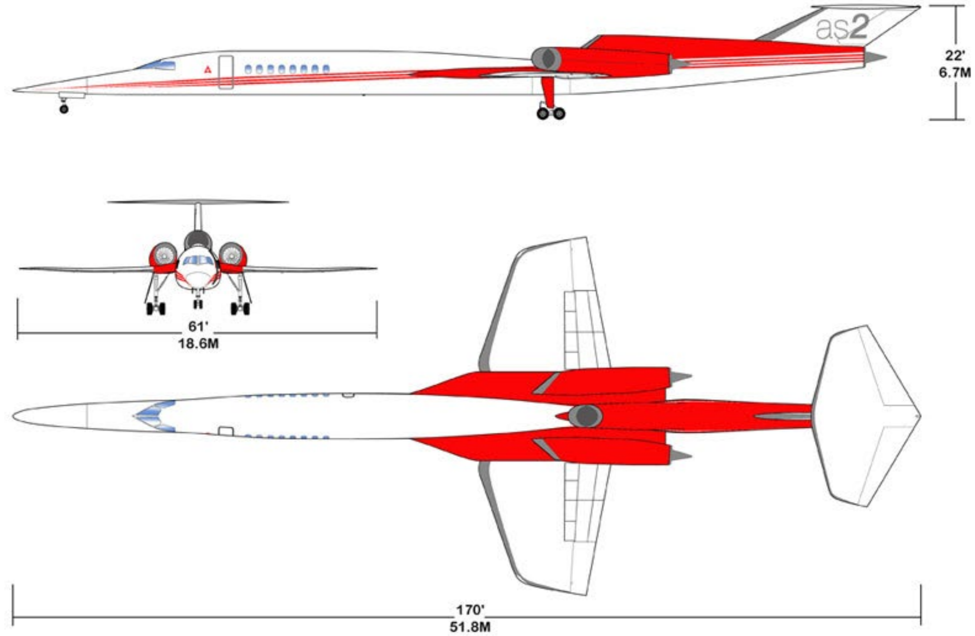
AS2 Performance Objectives and Specifications

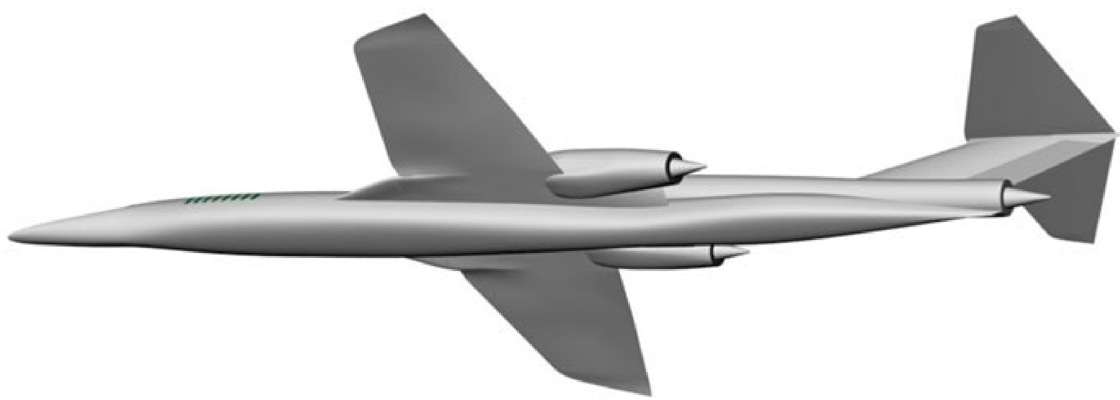
PERFORMANCE

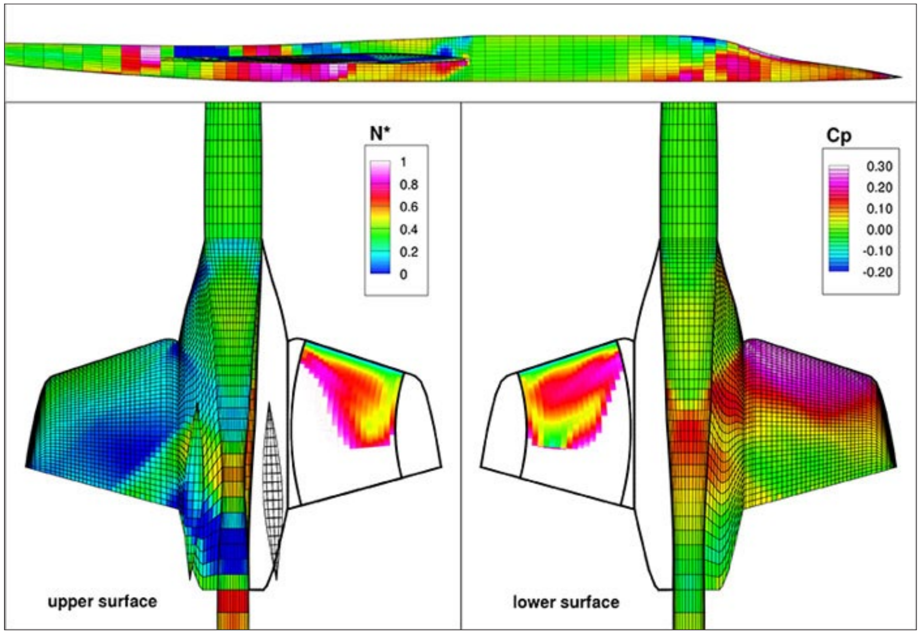
Max operating speed: 1.5 Mach
LRC, supersonic: 1.4 Mach
BOOMLESS CRUISEsm: 1.1 – 1.2 Mach
LRC, subsonic: .95 Mach
Approach speed: <135kts / 250kph
Max range IFR, Mach 1.4: 4,750nm / 8,797km
Max range IFR, Mach 0.95: 5,300nm / 9,816km
BFL at ISA S.L.: 7,500ft / 2,286m
MTOW: 121,000lbs / 54,884kg
BOW: 57,801lb / 26.218kg
Wing Area: 1,350sqft / 125sqm

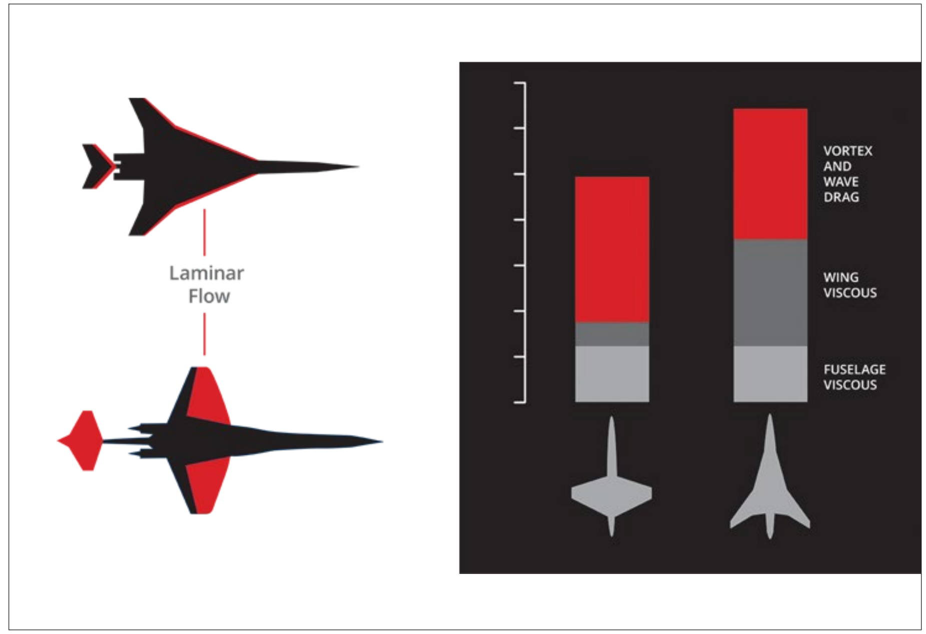
EXTERIOR DIMENSIONS

Length: 170ft / 51.8m
Width / Wingspan: 61ft / 18.6m
Height: 22ft / 6.7m









practical and efficient. The Concorde, for all its considerable technical advancements, failed in these key areas.

The Aerion AS2 is a fundamentally different aircraft in that it is efficient in both subsonic and supersonic flight, has greater range, and is more flexible in airport operations. This considerable difference is made possible by three critical advances: a new wing concept; new composite material technology; and advanced software, proprietary to Aerion, that permits analysis of complex transonic airflows.

The traditional solution for supersonic flight has been a delta wing shape. Spanwise airflow trips the boundary layer (the air flowing closest to the wing), causing turbulent airflow.

Aerion's thin wing and horizontal stabilizer, with moderately swept leading edges, reduce spanwise flow, allowing for laminar flow on these surfaces. Friction (viscous) drag over the wing is reduced by about 70 percent. When the wing and tail are integrated with an optimized airframe, net friction drag reduction is up to 20 percent which, in aeronautical terms, is a huge leap in efficiency.

COMPOSITES

The Aerion airframe will be constructed largely of carbon fiber composite structures, with titanium used for leading edges and some internal structures. The use of carbon fiber in major structures has become commonplace. The Boeing 787 and Airbus A350 XWB are largely constructed of this material. Its properties and construction processes are well understood. The AS2 will benefit from the low weight and high strength of carbon fiber, as well as the ability to craft composite materials into the precise and complex shapes required for superior aerodynamics. But of equal importance, carbon fiber wings will be extremely stiff, a requirement for holding the precise shape required for laminar flow and efficiency.

» TOUR DE SLOPE 2015 «

Uroš Šoštarič, uros.sostaric@siol.net

Photos by Damjan Romih, Gorazd Pisanec, Uroš Šoštarič

How to make the most of a R/C vacation? What destination to choose, and when? Each of us is wondering that each year because of a lot of options available. Of course, it is important to make a timely decision and start with the preparations. A lot of the work for a good R/C hobby vacation is done by making timely and thorough preparations.

For a while, I have been following soaring on the Umbria slope sites in central Italy. The slopes are vast and covered with grass, thus allowing great slope soaring. Each slope is unique, and therefore should be tried out at least once in a lifetime.

The Umbria landscape is located near the Italian coastal town of Ancona, which is located opposite to the Adriatic Sea from the Croatian town of Split, not far away from Livno and Kupres (Bosnia). I combined both coasts of the Adriatic Sea into an interesting and great modelling vacation.

1. Radivoj and I started our "Tour de Slope 2015" on the Vremščica slope. The photo shows the DG 1000S, 5m, made by Vlado Kobilica. At this slope, the start with a moderate wind is relatively easy, and also a start using a winch or bungee is possible. Thermals and in particular the SW wind enable great soaring. The landing is also relatively easy, irrespective of wind strength.

The term was already determined according to our traditional camp of Aerozaprega.si in Livno from 6th to 13th June 2015. The combination is good for every modeller involved in glider models and soaring on slopes or aero towing flights.

Together with my friend Radivoj Lenardon from Trieste, we quickly reached an agreement to do a “Tour de Slope 2015” as we called it.

The Tour itself began a few days prior to our departure to Umbria – we took advantage of a nice afternoon in May with a southwest wind for slope soaring on the Vremščica slope in Slovenia.

We are familiar with this slope and it seemed perfect for a start of our Tour; a kind of a warm-up.

Vremščica is a very popular slope amongst Austrian, Italian and Slovenian modellers because it provides excellent soaring in the south–southwest wind, combined with thermals. The slope is vast and unobstructed and offers a view of the Gulf of Trieste.

The conditions to land even the largest models are perfect because the landing is done against the wind in a laminar flow atmosphere onto a nice grassy surface.

Here we also discussed the final details of our Tour, since the logistics required quite a few preparations.

2. A break during an all-day soaring at Monte Vettore, seen in the background with its summit still covered in snow. All our soaring during the available days was done in the east slope, which allowed soaring from early morning until the evening. In the morning and in the evening I used my Xplorer 4000 for soaring, and during the day I used Limit K, making great use of the conditions throughout the entire day.

3. Limit K after an all-day soaring. The mighty Monte Vettore is in the background. The evening light in the mountains is particularly magical, and the entire coast of the Adriatic Sea is seen from this starting place.

The weather forecast for the entire week was sunny and warm, so there were really no reasons to delay. We made arrangements with some of our colleagues, leaving for Livno, to drive some of our models there, which would be used mainly for aero towing. We only took slope models with us to the Italian part of the Tour.

I don't have to tell you what it's like to go soaring on the slope, especially one so far away. It is essential to take along models for different weather conditions, different soaring techniques and different slopes.

My choices were the DG 1000 5m, Xplorer 4000 Electric and Limit K (Alex XL), and Radivoj had chosen Pilatus B4 4m and Piko Electro.

Saturday early morning, our vehicle was completely stuffed with models and other luggage of all kinds. The journey was pleasant in a beautiful morning, as the first cumulus clouds gathered over Apennine Mountains. This was just what motivated us – at least the thermal conditions will be as they are supposed to be, since the weather forecast was for NE–E, instead of the much anticipated SW–W wind.

There are four well-known specific regions in the area of the Umbria landscape: Monte Catria, Monte Subasio, Monte Cucco and Monte Vettore. We decided to have a go at the latter.

4. Departure with a ferry from the Gulf of Ancona (Italy) towards Split (Croatia). A pleasant and calm night ferry ride across the Adriatic Sea and towards new slopes.

In the middle of the day, we arrived at the mountain pass under the mighty Monte Vettore mountain (2476 m above sea level), where the road turns towards a small town of Castellucio di Norcia, the center of the Monti Sibillini National Park.

We settled in a nearby mountain cabin Rifugio degli Alpini nei Monti Sibillini at the altitude of 1560 metres, where modeller guests are quite common, and they offer everything necessary for accommodation; and what is especially expected in Italy, great home cooking meals – everything for a reasonable price.

Immediately behind the cabin is a slope for NE to SE winds. The conditions for soaring were just perfect, with a strong thermals and exactly the right slope wind.

This slope is not as appropriate as the other one using W winds, nevertheless, soaring with all models is still possible here. Landing can be done sideways upwind on the left-hand side towards the pass. The terrain for landing is not rocky nor too steep, and the slope soon turns towards the valley.

The scenery of the mighty Monte Vettore is astonishing and in the beginning of June, its summit is still covered in snow. If there is even a slightest bit of a mountaineer in you, you should head for the summit in the morning, before soaring, since the path is not technically difficult.

Here we met a Swiss modeller, living in Rome, who revealed us some details about soaring that come really handy, especially for the first visit. You know what it's like – to be "self-taught" is the most expensive school, and there is nothing better than a good and useful advice.

After two days we moved to a pleasant Taverna Castellucio in the town of Castellucio di Norcia, the center of a beautiful landscape, ideal for model soaring.

The Tavern is the center point for everybody arriving to this town with a purpose of soaring, whether kite soaring, paragliding or modelling. The surrounding grassy slopes are ideal for these kinds of sports. The small town is pleasant, tourist-friendly and is the center of a national park.

Towards the end of June, the fields surrounding the town change into a colourful palette of various crop blooming, particularly of lentil. Choosing amongst all of the great food is difficult, but I would recommend lentil dishes. Lentil thrives here and local people make all kinds of great dishes from it.

On our final third day, we enjoyed an abundance of morning soaring, but during the day a cumulonimbus cloud formed which reminded us that it was time to continue with our journey.

5. Our models completely filled the new hangar of AK Livno, built using the European funds. Since we had taken along over 50 models and the new hangar was already occupied by two gliders, we also used the old hangar.

6. A view from afar at the events at the Livno airport during our Aerozaprega camp. The vastness of the Livno field, the morning cumulus clouds and the airport infrastructure are well visible.

7. Radivoj (left) with his favourite model Ka6, together with Uroš Šoštarič (middle) and Zdenko Gačar (right). They are all in a great mood, thanks to great soaring and hanging out.

Monday evening we had a reservation for departure from the Gulf of Ancona with the Marco Polo ferry by the shipping line provider Jadrolinija, which maintains a regular connection between the Italian Gulf of Ancona and Croatian town of Split. This way we saved 1200 km of road around the Adriatic Sea for the price of a transportation of a personal vehicle and a sleeping cabin in the amount of 270 EUR for two persons.

The ferry ride lasts all night, and in the morning you wake up in Split in Croatia, which is not far from Livno in Bosnia and Herzegovina (90 km). Bosnia and Herzegovina is not a part of the EU, so on entering or leaving the country you are subjected to passenger and luggage control and customs inspection, where we had to report models. This procedure is quick and easy.

Livno airport was already a site of the traditional 6th camp of Aerozaprega.si in Livno, where we met up with our friends from Slovenia as well as the locals. Livno already feels almost like our home. With its airport, the local Aeroklub Livno is turning into a gliding and modelling center.

During our camp, the airport is reserved only for us with all its associated infrastructure; there is no other flying during this time. The infrastructure provides accommodation, sanitary facilities, restaurants, storage of models

8. There were quite some flights over 1000 metres AGL, as well as over 1200 metres. Obviously, to achieve such flights one must have an appropriate model, telemetry, good sight, great thermal conditions and of course some clouds for the background, because a model at such heights is very poorly visible on the blue sky. A descent from such heights also has to be carried out carefully.

in one of two hangars, and of course a grassy airport runway, which is great for a week of aero towing.

European funds have made renovation of the airport easier; an access road is already built with a parking place, as well as a fence around the airport and an additional hangar. A new asphalt runway is being built with a connection to the platform in front of both hangars.

The construction site itself did not bother us during our period of stay, and we are eagerly anticipating next year when the airport will be completely renovated.

Great weather from Italy continued also in Livno from morning until the evening, with a renowned “Livno thermals.”

Some of the senior modellers may remember the European and the World Championships in free flight models which took place in the middle of the 1980s in the Livno field. All the participants will always remember the magnificent nature, terrain and weather conditions; all these are also the reasons that attract us to visit this marvellous “grassland” again and again.

My Arcus (H Model) with a label UB was already waiting for me in the Livno hangar because my friends brought it along in their trailer. It didn’t take long to assemble it, as my friends were already gliding and the “tow-plane” was prepared at the starting place.

9. Zdenko (left) with his Ventus 2ax and Uroš Šoštarič (right) with his Arcus after one of the flights over 1200 metres AGL and the duration of over 2 hours. Obviously, this cannot be done without a great tow model, namely the pilot. In the middle is Dejan Laboš with his self-made Piper Super Cub. All models are scaled 1:3, and it is nice to see them in a "scale" aero towing.

10. In the nice calm atmosphere in the evening and with a wonderful natural scenery, we treated ourselves with a few flights for our own pleasure. The photo shows Ventus 2ax, 6m by Jure Marc. The background shows a cumulonimbus cloud that is breaking apart over Dinara, a mountain located on the border of Croatia and Bosnia and Herzegovina.

As early as the first start we experienced a low release of the glider at approx. 200 metres, flight duration of almost two hours, and a maximum height reached of a little bit over 1000 metres AGL.

Most flights during the next few days were similar. There is nothing better than to open a hangar in the morning, place the models on the starting place and soar throughout the day.

Due to all the thermals, sometimes an occasional cumulonimbus cloud forms, which only cools down the overheated summer air, and in the evening when it breaks apart allows soaring in a calm atmosphere.

In this year, 12 modellers from Slovenia and Italy with over fifty glider models and motor-powered model planes attended the camp of Aerozaprega.si. What could be better than great soaring, great soaring conditions, great food and great modeller company? It is especially important that here are no limitations about soaring and use of the airport, and that you have complete freedom to practice your hobby.

However, after a few days a change is a good thing, and so we headed towards the town of Kupres in the Kupres field at the altitude of 1200 metres, with a distance of about an hour drive from Livno.

The surrounding slopes are very appropriate for slope soaring for all wind directions. The Kupres field is quite similar to the landscape surrounding Monte Vettore, but its contents is completely different.

11. Besides soaring, food is the essential part of our gathering in Livno. It is of course impossible to do soaring throughout the entire day, and so we spent our time cooking true specialties, particularly local Bosnian specialties. Zdravko prepared us a delicious goulash in a real cauldron.

Another modeller joined our group, Armin from Oberstdorf in Germany, whom we had met in Livno and invited him along to Kupres.

We did our soaring on the slope of Gradina, which is suitable for NW to NE winds, while a larger slope of Stožer, where also one of the ski slopes is located, is suitable for SE–SW winds. Gradina is a low slope with an altitude difference of a bit over 100 metres, but with excellent thermal and additional dynamics of the north wind, and all twelve of us fully took advantage of all this.

It is easy accessible, or the locals can take you to the starting place with their van used by skydivers. The slope provides enough space for landing of all model kinds and sizes.

We were visited by a group of horsemen with tourists from abroad and of course by locals, who served us food and made our soaring easier.

The conditions were so perfect that we really made the most of soaring and the longest two flights took 3 hours and 45 minutes before we were all chased away by a cumulonimbus cloud.

But this caused no bad mood, since we had an appointment with Mate, a pioneer of paragliding in Kupres and now a ranch owner, engaged in equestrian tourism,

12. We are really excited about the daily trip to the slopes around the Kupres fields, just to break the habit from the happenings in Livno, and especially to do some serious soaring on the excellent slope of Gradina near the town of Kupres. Twelve modellers used their models for cutting the thermal over the slope, which was lifted by Zdenko's helicopter. A helicopter in the middle of the slope, surrounded by a few glider models, is really an unusual combination, but it is a part of all the freedom of soaring that Kupres offers.

13. For a conclusion, a group photo of all the attendees of the camp of Aerozaprega.si in Livno and slope soaring in Kupres. It was here where Radivoj and I completed our "Tour de Slope 2015," where we carried out soaring on three slopes in three different countries, drove approximately 2000 km and within this also crossed the Adriatic Sea.

who would also like to expand to modelling tourism on grasslands and slopes surrounding Kupres. Mate and his team prepare a delicious dinner for us each year with their Bosnian specialties, especially grilled meat.

So, with soaring in Kupres, Radivoj and I completed our Tour de Slope 2015 and enjoyed the remaining two days in aero towing and gliding in the Livno field.

The entire trip is more than just model soaring. It is about meeting new places, new people and their culture, and particularly meeting new modelling friends.

I hope that I will have a chance to repeat such a modelling vacation next year, of course with new places and slopes.

For more information, contact me at <uros.sostaric@siol.net>.